Building Onramps to the Information Superhighway: Designing, Implementing, and Using Local Museum Infrastructure

By Paul M. Helfrich, Ph.D.

Introduction

Do you recall that now-ancient Saturday Night Live skit with Dan Akroyd and Gilda Radnor where they parodied an infomercial on a new product that came in a whipped cream-sized can and was hawked as a “dessert topping” **and** “a floor wax?” Gilda glowingly cooed that this product was a dessert topping while Dan chided her that it was really a floor wax. Finally, they exchanged a conspiratorial glance and proclaimed that it was in fact **both a dessert topping and a floorwax**! This sums up my current view on the impact of what building onramps to the Information Superhighway in museums portends -- it provides a powerful set of technologies that promises to deliver different things to different people.

There is some confusion as to what the Information Superhighway really is. The first thing to understand is that the Information Superhighway and the Internet are **not** mutually inclusive: the Information Superhighway consists of a group of technologies **including** the Internet. These technologies form the basis of the complex web of telecommunications networks, including cable and telephone networks, wide area computer networks, satellite networks, and the people who use and maintain them. For the sake of simplicity (or is it sanity?), this paper is focusing on that portion of the Information Superhighway that is made up of a network of computer networks -- the Internet -- and its potential impact on museums.

What does the Internet promise to deliver initially to museums? The Internet can be perceived by different museum departments in a variety of ways based on their unique ways of doing business. Educators and teacher/trainers may see the promise of new resources and enhanced communication, exhibit developers may think in terms of exhibit analogs, marketing staff may think in terms of the online museum store, etc. However, these traditionally parochial museum departments (education, exhibits, programs, design, marketing, curatorial, etc.) all begin melt away in the face of an enabling technology that fosters the creation of networks of individuals who can communicate and collaborate, both **within** a single institution as well as **between** institutions.

Museums have traditionally been slower than businesses to integrate new technologies and infrastructure. With the advent of the World Wide Web, the Internet has been exploding into the awareness of the museum community. Many museums are still intimidated by the challenges inherent in integrating and supporting Internet

technologies into their institutions; the learning curve is perceived as being steep and expensive.

Is there any hope? Of course there is, but the decision to design, implement and use a new infrastructure largely depends on the strategic goals that any institution is working toward. Many museums are beginning to integrate the Internet into their existing programs. The museum community can learn from these projects as they develop, boldly going where few, if any, museums have gone before.

This paper stems from my involvement, along with a group of very talented and dedicated individuals, in a project called **The Science Learning Network** (SLN)**.** Begun in July of 1993 by the Franklin Institute Science Museum in Philadelphia, PA, and Unisys Corporation in Blue Bell, PA, this project is continuing for a three-year pilot program (1995**-**97) with $6 million in funding support from the National Science Foundation and Unisys Corporation.

The **SLN** consists of six science museums that have partnered with single K-8 schools:

- The Franklin Institute, The Levering School, Philadelphia School District, PA
- Museum of Science, Boston, MA, The Hosmer School, Watertown School District, MA
- Science Museum of Minnesota, The Museum Magnet School, St. Paul School District, MN
- Oregon Museum of Science and Industry, The Buckman School, Portland School District, OR
- The Exploratorium, San Francisco, CA, The Ross School, Marin County School District, CA
- Miami Museum of Science, Miami, FL, The Avocado School, Dade County School District, FL

This project is a collaborative effort to foster teacher professional development via telecomputing and inquiry-based science learning and teaching (see Appendix A, page 27, for more information on this exciting and challenging project).

Beginnings

In order to build a local onramp to the Internet, you must first have a global perspective of the many issues involved. Where should you begin? Strategic planning to integrate this technology so that it promotes the museum's mission is paramount. An institution must begin by accessing its priorities, how its educational programs are integrated with its mission, and by developing a technology plan as part of its strategic plan.

The results of a technology plan will provide the overall framework within which networking infrastructure can develop. It will provide a vision and a set of goals for implementation. The following is intended to sow the seeds for developing a technology plan that designs, implements, and promotes the use internetworking infrastructure in a museum setting.

Phase I: Designing Museum Infrastructure

In order to begin planning for the implementation and use of a new technology, an entire set of issues must be addressed and questions answered. Though it deals with a learning curve, this is actually the easiest part of the process.

Mission-based and Pedagogical Issues

Before you obtain your Internet connection, hire the necessary staff, and install the necessary wiring and hardware, there are some strategic issues and questions that you need to address:

1. Who is the audience you are serving with Internet resources and what priority do you assign to each part of your audience demographic? Is it the general Internet surfer? Teachers external to the museum? Teachers who regularly incorporate museum visits into their teaching? Museum professionals? Regional museum visitors with Internet access? Others?

2. How do you tailor content to serve these audiences? K-6, 7-12? Higher Education? Beginner, intermediate, advanced? Family groups? Underserved populations? Regional or global populations? Mono- or poly-lingual?

3. What will the focus be on creating your first Internet resources? Should you create a version -- an analog -- of your physical museum? Should you focus on a single project's goals (this may often be the initial funding source that provides Internet connectivity to a museum)?

4. What set of guidelines, both pedagogical and technical, do you employ when creating your Internet resources? Where can you find them?

5. How can you create online resources and activities that reflect what you do best in your institution (i.e. formal and informal inquiry-based teaching and learning)?

6. What are the best ways to use the enhanced communication functions that your new Internet-connected network provides? What are the best ways to use email? What are the best ways to use videoconferencing?

7. What are the new collaborative potentials that this technology facilitates? Museum to museum? Museum to school? Museum to home? Museum to industry?

The answers to these questions will provide you with a means of keeping your development efforts on track when you ultimately begin using the Internet. Be comforted by the fact that there aren't answers to all of these questions. They are being created, refined, and expanded even as you read this.

Conceptual Issues

It is of critical importance that you understand the nature of the beast that you are preparing to deal with, particularly when preparing to commit limited staff resources and funds to enter a sophisticated technical arena. A consultant or knowledgeable staff member can play a very important role here to help fill in conceptual gaps, enabling you to move forward.

What is the Internet?

A child of the Cold War, the Internet was originally based on the needs of American-based research scientists and military personnel. They wanted the ability to communicate with each other over a widely dispersed and distributed computer network in the event of a catastrophic attack. The Internet is thus a network of computer networks, a set of computer hardware architectures, software standards, and protocols that allow for commerce (data exchange) on a distributed global scale. This network can be partially working at any given moment and still send its data streams from point to point. It is not owned, maintained, or paid for by any single organization. It can be accessed by a variety of different flavored computers (Macs, Windows PCs, Unix) running a gamut of software.

How can we access the Internet?

There are three basic solutions:

1. The **most economical solution** involves a dedicated phone line, a modem, and a computer configured with appropriate software. Charges include a one-time fee for the computer (approximately $2,000), staff time to configure the software (1-2 hours once you have it down), a monthly phone bill (about $30 per month depending on location), and a monthly Internet provider charge (approximately $20-80 depending on services

offered **--** SLIP, PPP, email, newsgroup accounts). Keep in mind there are local and regional variations here.

This solution provides you with access to Internet resources and email. It does not provide you with the ability to become an information provider to Internet users.

2. The **enterprise-wide solution** is proportionally more expensive. This includes some type of local area network with a direct connection to an Internet provider. There is a large variation for individual configurations here, so I won't offer specific prices. Suffice to say that this solution ups the ante considerably and requires the appropriate funding as well as staff contingent to implement and maintain.

3. This solution is a **compromise between #1 and #2**. Essentially, you can alleviate some of the up front work and cost associated with installing a local area network by renting (or some other arrangement) a web server from a third party. The benefits are reduced staff support required (the third party maintains the server), reduced costs by eliminating your own web server (you can always add one later), and lowering the cost (and speed) of your Internet connection (you can always increase the cost and speed later).

This is not as daunting as it may at first seem. Many larger museums already have local area networks and Internet connections with support staff in place. The Science Learning Network consists of six museums (there are many others) that have local area networks and T1 (high speed) connections in place. You can save large amounts of time and money by using these as models for your own replication.

What is involved with installing and using a local area network (LAN)?

This is the basic ingredient of an enterprise-wide connection to the Internet. It consists of any one of a myriad configurations. It is best to engage expert help when planning, designing, and installing a LAN. It can be done in phases and usually begins with the installation of a network wiring "backbone." A backbone is the basic wiring scheme that forms a powerful skeleton that is connected to the Internet. All networked subgroups will eventually be connected to it.

The basic premise of using a LAN is that of client-server computing. A client computer is usually a desktop computer like a '486 or PowerMac. A client computer is configured with software that allows it to access information provided by a server. One can then process and save that information to one's own (client) hard drive or print it locally.

A server is usually a more powerful computer that provides information, in myriad forms, to client computers. Servers are generally not used by an individual for office-type computing pursuits. They are created to transparently provide software

applications or information to desktop client computers. This is the type of computer that you will use to provide information and resources to Internet users.

Finally, your LAN may need to have a security system installed called a **firewall**. This is a little black box with lights that serves as a shield against those unsavory denizens of cyberspace that would break into and potentially wreak havoc on your network. The firewall is an important consideration in an enterprise-wide LAN that includes connections to such mission-critical systems as finance, payroll, personnel, membership, or ticketing.

What is an Internet Provider?

This is one of a number of rapidly growing of companies that will provide the actual hardware to connect some type of dedicated data line from its source to your museum's building and provide and manage the send/receive data stream.

There are a variety of package deals that you can negotiate. Among the most important options you'll want to consider are 1. providing maintenance on the hardware (called a router and CSU/DSU) that serves as a gateway between your internal network and your Internet connection to the rest of the world, and 2. the data rate (called bandwidth) that you'll want to use.

Providing maintenance and bandwidth services are the Internet provider's bread and butter, so expect to pay for these items (of course, these are primary opportunities for museum sponsorships). You may want to begin with a less expensive bandwidth (56K, 128K ISDN, or fractional T1). You can then increase the size of the data rate as you expand your use.

What is the World Wide Web (WWW)?

This is a set of protocols and standards, referred to earlier, by which your resource production staff will format and serve any information intended for Internet users. These protocols provide a method of formatting, serving via a network and viewing multimedia information in the form of text, graphics, animation, video, and sound.

The Web was conceptualized by Tim Berners-Lee and Robert Cailliau in 1989-90. It revolutionized access to information on the Internet by implementing a unique means of organizing information called **hypermedia**. One of the primary organizing principles for information on the Web is that of a book (instead of a house or exhibit hall) in which you can move to any page via a **hyperlink**. A hyperlink is really just an address that includes the exact location of the computer and what folder or directory in which that particular page is stored. The amazing concept here is that you can immediately travel to any page on the Web if you know its hyperlinked address (also called a URL or

Uniform **R**esource **L**ocator). **The Web is thus inherently nonhierarchical in its design,** which presents a challenge when designing online resources**.**

The Web, as it exists in 1995, is still primarily a text-based medium. When designing resources for the Web you must keep this in mind: it is a common notion in the museum community that “no one reads exhibit copy.” While this is not exactly the case, various studies have shown that well over 80% of museum visitors do not read some or all of an exhibit’s copy and labels. Care must be given to integrate graphic and multimedia design elements that **minimize the time** an online visitor spends reading.

What is HTML?

This is the markup language that your staff will need to learn so they can format information resources to serve to Internet users. **H**yper**T**ext **M**arkup **L**anguage (HTML) is a method of coding multimedia elements -- plain text, graphics, animation, video and sound -- so they can be viewed by a piece of software called a browser.

HTML is supposed to be a standard, but there are many features that are and are not supported by various browsers. The current standard is HTML v.2.0, but that hasn’t been fully accepted, approved, or implemented by all of the many players who serve information via the Internet. This is more a feature of the non-centralized (distributed) nature of the Internet than ill will on anyone’s part.

What is Mosaic, Netscape, and Lynx?

These are the three currently most popular software packages for accessing or browsing information on the World Wide Web. Hence they are known as browsers. They are available as freeware (free to educational and non-profit organizations) and allow users to access and view anything formatted in HTML available on the Internet or a desktop computer.

One thing that is unique about these three WWW browsers is that they are available for all three of the basic computer platforms -- Windows, Mac, and Unix. Thus they provide a uniform look and feel regardless of which computer you use.

Mosaic and Netscape share a fundamental difference from Lynx. The former are graphical user interfaces that allow for viewing information in multimedia formats (video clips, pictures, sound, and animation as well as text). They also allow you to send email and access Internet newsgroups in a graphical format (icons, pictures, fonts, etc.). Lynx, on the other hand, is a text browser and is therefore not multimedia-enabled, providing a user with access to text elements only. You can also send email from within Lynx.

The advantage of using Lynx is that anyone with a low speed modem connection (300 to 9600 pieces of information per second) can access HTML-formatted resources via the Internet. They just don't get all of the bells and whistles (cool graphics, videos, and sounds) when accessing World Wide Web information.

To maximize access by a variety of different users, any information that you decide to serve to Internet visitors will need to be designed to look good in all three of these browsers.

What staff needs must be defined for Internet Access?

In order to create and maintain an Internet server and develop useful mission-based resources, there are a variety of interrelated roles that need to be examined and fulfilled. The following are not mutually inclusive, but provide a point of departure for creating a WWW resource production team.

1. **The Information Systems Specialist (system administrator)**. This is a new role for any museum staff. This person needs to have a strong technical background in network computing. They need to have Unix experience, as WWW servers and resource development computers exist in a Unix environment.

This person will collaborate in the design, production, and maintenance of WWW resources, provide limited technical support to museum staff, log system usage, optimize system resources, and be responsible for backing up and archiving all data. This person **will not** have time to provide staff and hardware support for enterprise-wide computing. Don't even consider killing two birds with one stone here -- the result will be an overextended, burnt out, guaranteed mess of a situation.

2. **The Online Resource Developer**. This role has many permutations, particularly as I've seen it manifested in the six museums involved in the Science Learning Network Project. This is a synthesis of the exhibit researcher/developer, text/label writer, teacher/trainer, and curricula developer newly metamorphosed into an online resource developer.

This person must have excellent writing skills. Be mindful that Web resources are primarily text-based and not multimedia-based. Classroom teaching experience is a must if this person will be designing resources for use in an Internet-enabled classroom setting.

3. **The Multimedia Designer**. This role also has several variations to it. The multimedia designer collaborates with the Web resource production team to create video clips, animations, graphics, and even audio clips that support the pedagogical intent and content of online resources. This role covers a wide range of skills, so you are likely to

end up hiring someone who can do some but not all of these things. I would recommend someone with video production skills over graphic design skills in this role as graphic design can be covered separately (see next item).

4. **The Computer Graphic Designer**. A natural evolution of the traditional graphic designer who supports museum exhibitions and print materials, this role is critical to developing an aesthetically pleasing look and feel for your online resources. This can be a part-time role that a current graphic designer grows into, as it will include many of the software tools that are currently being used to support exhibits and page layout work.

5. **The Project Leader**. This role is also subject to variations on the theme. This is the person who needs to be equal parts psychologist, computer expert, pedagogue, Internet savant, and project manager. A new breed, this person works with all of the other team members to insure that all resource development fulfills the project's or museum's goals and is delivered on time and on budget. This role can be filled by someone with either a strong classroom teaching, exhibit development, or public programs background. The skills required will be tailored to match the specific application or project goals.

Allow me to plug the notion that these folks, who will tend to be very dedicated and passionate about their work, should receive an equitable salary. If they don't, you will only be providing training for someone who will eventually leave to get a higher salary for performing a similar job elsewhere. These are highly skilled jobs and should be treated with appropriate care when positioning them within your institution's salary scale.

Technical Issues

There is another very important software protocol that is critical to the successful design of the museum-wide LAN. It is called **T**ransmission **C**ontrol **P**rotocol/**I**nternet **P**rotocol or TCP/IP. TCP/IP was developed in the late 60s and early 70s as a means of sending information across the wide area network and would still reach its destination if some or most of the network were destroyed. TCP/IP allows a single computer file (for example, an email message) to be broken down into discreet packages called packets. It then sends these packets, each with a unique label identifying what composite file they are part of and destination address, out across the wide area network. These packets can each travel unique paths to their inevitable destination and are reassembled by the receiving computer (called a mail server) into a single file that you ultimately read as an email message.

In order to serve information to Internet users, you will need to integrate and run a software application on your World Wide Web server that uses a protocol called HTTP (**H**yper**T**ext **T**ransfer **P**rotocol). This can be run on a Unix, PowerMac, or Windows operating system. A real benefit here is that you don't need a $10,000 computer in order to run http server software. A '486 or PowerMac can run this software and serve hundreds of simultaneous requests by users.

One of the many benefits you get when selecting a flavor of Unix to run your Web server is the use of CGI (the **C**ommon **G**ateway **I**nterface). This is another one of those protocols (really a scripting language) that allows you to create and manage **forms**, a unique way to solicit input from users of your Web resources (remember: they're in HTML format).

A form lets a user enter text information, like their name, or provide input to ongoing interactive online conversations. Forms allow one of the most basic levels of interactivity with your Web resources. Its evolutionary path is one of great interest, for it will allow new ways for interactivity online, and it's interactivity that science museums are all about (as far as a methodology, anyway).

CGI scripting also allows you to implement a feature called **image mapping**. An image map consists of a hyperlinked graphic image (called an inline graphic) in which you have predefined certain zones within the image with particular hyperlinks. For example, a picture with five individuals could be have an image map that allows a user to click on any individual in the image and jump to one of five separate web pages.

Another useful feature of image mapping is the ability to design navigational aids via graphic images. For example, the words HOME, NEXT, BACK, HELP could all be included in an attractively designed image map that could serve as a navigational aid on many or all of your web pages.

Economic Issues

One shouldn't enter lightly into this arena without having adequate funding to install, support, and maintain your local area network. Any technology plan must take this into careful consideration. Computer networks require constant care, just like an exhibit on the museum floor. This care comes with a price tag. Immediate things to plan for are the network wiring (backbone and wire runs to user groups), hardware, software, staff, and Internet connectivity. It is prudent to plan for a minimum of five years, including funds for hardware upgrades, software upgrades, and adding new users.

Raising the funds to pay for this endeavor can be accomplished in a variety of ways. This year the Department of Commerce and the National Science Foundation will

provide tens of millions of dollars to support a variety of projects. All are a subset of the NII and GII -- National Information Infrastructure and Global Information Infrastructure. These initiatives have been instituted by the Clinton/Gore Whitehouse and are providing seed money for building the Information Superhighway in all of its many variations at state and local levels.

Corporate partnerships are another excellent avenue to raise funds. The Science Learning Network project has been the beneficiary of a partnership between the Franklin Institute Science Museum in Philadelphia, PA, and Unisys Corporation in Blue Bell, PA. Unisys has committed to close to $4 million from 1993-97 to help develop this telecomputing project. Unisys has generously contributed cash, in-kind hardware, and in-kind services to facilitate this endeavor.

Political Issues

It is common knowledge that if there isn't a strategic commitment to implementing and maintaining infrastructure from the top-down in any organization, a technology initiative will wither and die on the proverbial vine. It is critical that the senior level buys in to any technological initiative of this sort.

There needs to be a strong commitment to continued staff training and technical support. If funding ends and there is no effective strategy in place to maintain staff and equipment, you're in big trouble. Whether you are beginning to travel down the path to techno-nirvana or techno-hell will be determined by how you've answered the following questions:

1. How does the installation of a technical infrastructure fit into your museum's mission?

Some answers include: administrative/finance/admissions/staff productivity enhancement, mission-based projects, construction and use of computer resource center for public programs and teacher training, enhanced internal and external communication capabilities, and enhanced potential for collaborative projects with other museums, schools, and industry partners.

2. Who will get connected to the museum LAN? When? Why?

The phasing of staff connectivity will relate to contents of your strategic and technology plan. Finance, administration, and admissions are key elements to keeping a museum running smoothly and seem to be likely first candidates. Next come the museum staff that are working on various exhibits, outreach programs, and teacher training projects.

3. Do you have adequate funding for the next three years to support staff, hardware, software, and Internet connectivity?

If you answer “no” to this question then you should seriously consider waiting until adequate funding is in place or else significantly scale down your technology plan’s goals.

4. How will we maintain and leverage this commitment?

The staff involved in creating Internet resources will need to constantly monitor technical (Mosaic++, HTML++, CGI++, connectivity costs and options, and email evolutionary paths) and educational developments (what other telecomputing projects are beginning, continuing, or finishing that can offer important ideas so we don’t have to reinvent the wheel?).

Risk-taking, experimenting, and pushing the envelope (exhibit projects, teacher development projects, online programs) are key elements in this arena. Commitment to hardware maintenance and upgrading every 3-5 years is also important. Forming new partnerships with museum, school, and industry partners as museum staff accrue experience will leverage your investment in staff and infrastructure. Fee for service opportunities will be a natural evolution. For example, the Philadelphia School District has over 12,000 teachers who will form the basis of teacher training programs in the Franklin Institute’s Museum Network Resource Center in the coming 1996-97 school year.

A museum technology plan should provide support for **both** MAC and Windows platforms. The selection of one platform **over the other** is largely a religious issue, in my view, based on faith rather than a clear perception that the two platforms are converging with great rapidity, are increasingly present in schools, and have a robust set of common applications.

Finally, it is important to have backup, archiving, and disaster recovery strategies in place before you turn the key on your new network. Regular backups of valuable resources and offsite storage of digital archives are important features of a redundant backup strategy.

Phase II: Implementing Museum Infrastructure

This phase is the beginning of the acid test. Once you have addressed the preceding issues and answered the preceding questions, you are ready to put theory into practice. Of course this is, in many ways, the most challenging part of the process. But if everything were easy would life be any fun?

Mission-Based and Pedagogical Issues

When beginning an Internet-based project, care must be given to establishing a set of checks and balances between staff complements, particularly those in different departments. Funded projects seem to have their own evolutionary paths and may result in the cart leading the horse. When setting up the development teams for projects, who decides what is a good design? Should this be done by a small, empowered project team or a global museum committee? Can there be a mixture of both?

Rather than elaborate here, let me note that the Science Learning Network's six museum partners are currently experimenting with a variety of resource production and management models: from matrix managed teams to local empowered teams. This reflects the nature in which each museum perceives this project fitting in with its own management model.

Integrating inquiry-based pedagogy into projects is a key if an Internet-based project is to succeed. At the Franklin Institute, we spent several months (in late '93 and early '94) debating what our niche as a provider of online resources was. We came to the conclusion that we would be competing with all of the other information providers: cable companies, online services (Compuserve, AOL, etc.), the Internet, etc. If we were going to add value to the information marketplace and provide valuable online resources, then we needed to be sure that our resources were organized according to our unique approach of hands-on inquiry learning. Period.

It is my unyielding belief that the science museum community contains a large, untapped source of creative energy and instructional design expertise that will be used to develop unique online resources (whether we will ever be able to generate revenue from them is another matter, of course). Our hands-on approach to learning and teaching is what makes us unique from theme parks and other online services. We don't focus on providing answers initially, but guiding the process of discovery using a variety of inquiry-based strategies. Realizing this potential vis a vis online resources is the promise inherent in the work currently being done by the resource production teams in the Science Learning Network project.

Technical Issues

Be prepared to plan an adequate amount of time for the installation of a local area network. The network must be designed within budget constraints, the wiring backbone installed with subsequent wiring runs to offices and production facilities, network

hardware, and computers specified, ordered, installed, and configured. This always takes longer than initially thought; Murphy's Law seems to constantly lurk around the next corner. Plan enough time and budget enough funds to do the job right the first time, especially if this is an enterprise-wide endeavor. This may seem obvious, so this is just a reminder.

If you plan on a low bandwidth solution (14.4 baud modem access over telephone lines), this will take proportionally less time and money. Before committing to a single topology solution, you should consider all of your options. Ultimately, the bottom line is dollars and cents.

Personnel Issues

Hiring new staff always seems to take much longer than anticipated. Until you get the job description written, approved by Human Resources, posted, advertised, candidates interviewed, a job offer tendered, and subsequent start dates identified, three months can easily elapse. Then add the sixty days that it may take to get staff teams up to speed and five months will have elapsed since you began this part of the project's implementation.

Staff training is another important issue. Given the nature of salary structures in the nonprofit arena, it is likely that you will hire someone who comes to their new job with an incomplete set of skills. You will need to provide adequate budget support to provide your online developers with opportunities for maintaining and improving their skills in relevant areas: UNIX, Mac, Windows, CGI, HTML, Local Area Networking, and TCP/IP for starters.

Economic Issues

It is highly likely that the initial funding raised for Internet connectivity will be grant- or sponsorship-related. Depending on the period covered by the grant, you will need to plan for covering this expense from other sources after the grant period expires. Internet connectivity and computer network support are expense line items that you must begin to think of in terms of standard overhead expense, similar to a utility bill or administrative staff. You can't run a museum without the support of water, electricity, or phones and you can't run a LAN and continue to provide resources to your Internet audience without working infrastructure and support staff.

It makes no sense to implement an enterprise-wide technology and think that you will be able to fund it solely with on sponsorships and grants. The notion is that once the infrastructure is funded and in place, it is your job to integrate it into the daily fabric of

doing business. And that means getting your Board of Trustees to approve funds for supporting your investment in implementing this infrastructure.

The costs for a high bandwidth connection currently run between $10-12 thousand per year. As more and more providers compete to provide you with their services, this rate will drop somewhat. There is a one-time installation charge that can go as high as $12-14 thousand. Other areas for yearly funding include maintenance contracts, hardware, and software upgrades. You can leverage your investment -- your network's computers -- by purchasing accelerator cards, RAM, and hard drive upgrades instead of purchasing new machines.

Finally, you need to think in terms of a 5-10 year hardware and software upgrade plan. There is nothing more offensive than to see a computer lab of under-powered machines still chugging away long after their useful life has passed. While this notion is still on the fringes of any sort of planning normally done in American industry, it should be a perspective that finds it way into your museum technology plan.

Political Issues

Integrating a new technology into the culture of your museum can be problematic. The pitfalls can range from a single group controlling and not sharing the resources with the rest of the institution to various departments competing with each other to control access to the web server. As this is still a very new situation in the Science Learning Network museums, the jury is still out on the best way to implement a management structure.

At the Franklin Institute, we are experimenting with a matrix management paradigm. In theory and usually in practice, this allows a cross-departmental view and access to developing the online museum. We felt that is was critical to integrate the Education, Programs, Exhibits, Program Support, Marketing/PR, and Technical staff. In reality, our SLN project development team is working with a degree of isolation from the rest of the museum. While this serves the goals of the SLN project very well, it doesn't serve the larger goals of the institution as well. Thus we are currently forming a museum-wide committee to oversee defining the goals and prioritizing the content for our online museum.

The last issue to raise is that of the haves and have-nots. As a museum network requires a phased installation, the inevitable result is that some people get connected first and others will have to wait. The initial euphoria of the announcement of an exciting new project can quickly turn into resentment if not handled carefully from the beginning. This is where all-staff meetings to communicate the technology plan and its implementation can help. Giving staff a timeframe helps manage their expectations and

provides a glimmer of hope for joining those (perceived as more important) staff who get their connections first.

Phase III: Utilization

This is the challenging but ultimately most enjoyable part of the process. It is also the **real** acid test. This is where, with any luck, you finally get to harvest the fruits of your labors. All of the planning and implementing work have been accomplished, in a phased manner of course, and you and your museum staff stand ready to reap the benefits of joining the online community... I wish it were really that simple. Actually, it should be clear by this point that designing, implementing, and using museum internetworking infrastructure are, to some degree, concurrent processes.

So we've finally arrived at the chicken and egg paradox of this getting-connected-to-the-Internet business. That is, can you really design the content of your online resources before your staff have access to and experience with the medium in which they will publish them? Which comes first -- the network or the content?

Once you have staff members who are actively using the Internet, it will take them sixty to ninety days to explore and reach a comfort level in working with a team in this medium, even if it isn't entirely new. At some point during this transition you should be articulating some new and refining some older questions concerning the content and goals of your online museum (you should also be looking at other online museums and their amazing variety of online content as sources of inspiration).

Conceptual Issues

Should there be a strong coupling between the physical and online museums?

The advantage of strongly coupling the physical and online museums is that of you can translate and thus extend your unique identity online. This is essentially what all six of the SLN museums have accomplished with their initial institutional representations online.

The next question, then, is what is the potential of the weaker couplings with the physical museum? Do the online museums and the online audiences that we are cultivating exist in a unique, separate environment? Do they exist primarily as an outreach of the physical museum, or is there some middle ground? These questions may be answered by the evolution of online audiences, and whether it is possible to create a viable fee for a service online model.

What is the impact of the medium (the World Wide Web) in which the online museum will exist on its design?

As of April 1995, most people haven't heard of the Internet, much less the World Wide Web. And since the medium is the message, there can be no message without a delivery medium. The point here is that this is a new frontier for exploration, work in it is just beginning, and most people, at present, haven't even heard of it much less have access to it.

Due to the nature of the Web's nonhierarchical hypermedia construction, a user can immediately access and download any page they want, regardless of where it exists within a hierarchically-designed set of pages, once they know its address (URL). When designing Web resources you mustn't lose sight of this simple fact -- if an online visitor finds something valuable they will go directly to it and **bypass** all other "nonvaluable" information. It may be more accurate to call online visitors **browsers**, since browsing information is their primary activity until they find something of interest.

Remember that with the information currently published via the Web, **you can point from any one of your pages to any other page within the global totality of the Web!** You could even include the addresses (URLs) of images, movies, and sounds on other people's servers **in your own pages**. This way, when someone accesses your page they could download the HTML file from your server and the images, movies, and sounds from three other servers, **creating a unique page** on their computer. Scary and way cool all at once!

This situation generates a whole new set of questions and constraints. You now have the freedom to design for a single online global museum, one made up of various divisions -- science and technology, art, aquaria, zoos, natural history and science, and other specialized subjects. One of the primary objectives in creating your online museum should thus be to make your resources and programs unique so they stand out from the crowd. This reinforces the notion of adding value through personalizing your online museum, adding programs and activities that add a strong human dimension to the online experience.

The user-driven nature of the Web vs. vanity publishing

One of the double-edged qualities of the World Wide Web environment is that anyone with access to a server can become an information publisher. While this is great for freedom of speech, expression, and the democratization of cyberspace, the downside is that the quality of the information now available is often less than desirable. In fact, from an educational perspective, a lot of it is pure noise.

Still the Web is driven by its users and if we are to foster a user-driven environment that produces high quality resources as an added value to our own, then we will need to work carefully to facilitate and educate new users. I'm thinking particularly of the 60-70 teachers that we will be working with in the Science Learning Network project this summer and thereafter. Producing resources in a multimedia environment requires a skilled team of designers and developers. It is naive to think that everyone is going to create and publish well-designed online resources.

This is an evolutionary process. We are in a similar situation to the early days of desktop publishing when many people felt empowered to produce high quality print materials with the ease of turning on a computer. In time many people realized that design experience or a design background was necessary to produce quality desktop publications. In other words, it wasn't the hardware and software that created quality but skilled individuals using these tools. The same holds true for developing Web resources.

How can the online museum enhance visits to the physical museum?

The real question here is will the online museum be able to establish its own online identity and audience? If it turns out that the global audience is less infatuated with your online museum, then the more significant audience segment may be ultimately be found in your own backyard.

The online museum can also cater to its regional audience, leveraging pre- and post-visit opportunities with museum visits. The wonderful educational playgrounds found in physical museums can be supported by online resources and programs. Much work must still be done, however, to define the audience so that appropriate materials and staff-supported programs can be designed and offered online.

Teachers and K-12 students are primary candidates to cultivate in your local region. Visits to the museum can be greatly enhanced with online resources and programs that complement the latest traveling exhibits, omnimax films, planetarium shows, floor demonstrations, and auditorium shows.

What are the Intellectual Property Issues?

These issues are beyond the scope of this paper but deserve a brief mention. The moment you create any digital resource it is automatically copyrighted according to present copyright laws, whether or not you display a copyright notification. However, the moment that you publish any resource online you have made it available for anyone to download to their computer. Once they download it to their computer's RAM (**R**andom **A**ccess **M**emory), what rights do they and you, the publisher, have? Can they

save it to their hard drive for later use or print it out to read without your permission? What if you charge a fee for access as opposed to free access?

There are still many legal and ethical questions to be raised and answered in the coming years concerning the use and reuse of online resources. Another situation looms with the teachers involved in our Science Learning Network project. We hope to be able to provide them with their own T1 lines and Web servers. Later this year they will begin to create their own resources and publish them online. Who will own the resources? Will the school or school district claim copyright ownership of the students' and teachers' work? Who will be entitled to the monies made from a CD-ROM of the students best projects? Stay tuned for developments on this front.

What are some of the common problems in using the Internet?

Providing a connection to the Internet opens the door to a whole new world. There are many new tools to learn, proper behavior ("netiquette") to learn, and challenges to face. There is a transition that everyone goes through when given access to this environment.

One of the first conditions that Internet access presents to users is information overload. Learning to deal with access to irrelevant information is one of the rites of passage when first getting connected to something as rich and varied as the Internet. This can lead to job burnout, so it should be taken seriously.

One strategy for dealing with the situation is to offer a staff training program. The Franklin Institute Science Museum is fortunate enough to have a museum-wide program of staff training on a variety of subjects -- from customer service to using the Unisystem (a museum-wide LAN that serves logistical and educational programs). As we implement a museum-wide LAN with Internet access, we are in the planning stages for a staff training course using the Internet. It will cover the basics of Internet use: email/listservs, WWW browsers (integrating gopher, ftp, telnet, newsgroups), and videoconferencing (CUSeeMe).

You will also quickly discover that your system administrator is an extremely popular person. Every time a new version of Netscape or Mosaic comes out, a software application doesn't work the same way it did yesterday, a hard drive crashes, etc., this individual will assume center stage. Finding a good system administrator will save you lots of headaches and will allow you to concentrate on the important things like creating quality online resources and programs.

Another problem is that there is consistently heavy Internet traffic during 9 A.M. to 5 P.M. prime time. This makes it difficult to connect to some locations and use their

resources. While this is a regional phenomena, based on the topology of the actual Internet Provider's system, it is still worth mentioning.

Lastly, when using a videoconferencing system like CUSeeMe you can overload your internal network with the data-intensive stream and wreak havoc on other users' access speed. Bandwidth constraints are one of the primary reasons for upgrading your Internet connection to a higher speed as soon as it financially feasible. **You will always be in need of higher bandwidth.**

What are some of the common problems maintaining resources on the Internet?

A potential problem is maintaining current links within your online resources. As you build resources and integrate other cool Internet hyperlinks you will need to check those hyperlinks periodically to insure that they are still valid. Someday this process will be automated but don't hold your breath for it to happen in the near term. This will be one of your resource development teams' most important jobs. Nothing is more frustrating, for an online visitor, than trying to jump to a new hyperlink only to find that is broken. The message to your online visitors will be that you don't keep up to date, so take this to heart.

Strategies for Online Resource and Program Design

First steps -- to recap the design and planning process, define your:

- niche as an online information provider.
- pedagogical model, based on museum mission.
- audience, prioritize audience demographics.
- goals for creating online resources.

Next steps -- organizing strategies to begin creating online resources:

The initial decision to strongly couple the physical and online museums provides a natural extension of the physical museum and a good place to begin. You could then select themes for resource development (virtual exhibits, programs, activities, collections, etc.) and prioritize them. A good place to start is with your most visible, recognizable elements that your regional audience perceives as being uniquely yours (even though the Web is primarily a text-based medium, the ability to embed graphics and movie clips makes it an extremely visual text-based medium).

- **virtual exhibits** -- Ben Franklin (http://sln.fi.edu/franklin/rotten.html), The Heart (http://sln.fi.edu/biosci/heart.html)

- **virtual exhibit supporting a traveling exhibit** -- (http://sln.fl.edu/~helfrich/music/intro.html)
- **inquiry-based units of study -- Wind: Our Fierce Friend** (http://sln.fi.edu/tfi/units/energy/wind.html)
- **monthly publications -- InQuiry Almanack** (http://sln.fi.edu/qanda/qanda.html), **The Philadelphia Inquirer** (http://sln.fi.edu/tfi/publications/inquirer/inq.html)
- **galleries -- photo / video** (http://sunsite.unc.edu/expo/deadsea.scrolls.exhibit/intro.html)
- **telerobots** -- (http://cwis.usc.edu:80/dept/raiders/)
- **organized Hotlists/Bookmarks of Internet resources** -- (http://sln.fi.edu/tfi/jump.html, http://sln.fi.edu/tfi/hotlists/hotlists.html)
- **virtual interactives** -- html, forms-based, on the fly software engines (http://rs560.cl.msu.edu/weather/interactive.html)
- **computer simulations and modeling** -- the National Oceanic and Atmospheric Administration allows access to its databases via custom CGI scripts that allows users to explore various atmospheric models (http://ferret.wrc.noaa.gov/ferret/main-menu.html)

At the Franklin Institute, we began by developing a virtual exhibit on our namesake -- Ben Franklin (http://sln.fi.edu/franklin/rotten.html). The next step was to create an analog to our physical museum that we called TFI Online. This provided the skeleton of the online museum and is itself based on the physical museum (http://sln.fi.edu). Then we created a virtual Heart Exhibit (http://sln.fi.edu/biosci/heart.html) to enhance one of the most recognizable and memorable features from a real time visit to Philadelphia -- our giant walk-through heart located in our Bioscience Exhibit.

This selecting and ordering of themes has played out in a variety of ways within the Science Learning Network. Several museums in the SLN began by creating the skeleton of their online museum before they began work on virtual exhibits, programs, etc. Some did the opposite. The net result evens out in the long run. Virtual exhibits subsequently require an online museum to exist within to provide a contextual framework, and an online museum requires exhibits, programs, and other activities to make it viable.

Next steps -- navigational aids to include in the design of your online resources:

- **hierarchical hyperlinks** -- organize the contents of online exhibits, activities and other resources via **image maps** (home, forward, back, help, etc.) or p**lain text.**
- **custom search engines** -- LYCOS, World Wide Web Worm, Harvest, etc., can be customized to facilitate searches of your Web server's contents and all of the hyperlinks that your resources point to. Check out the Franklin Institute's customized version of LYCOS search (http://sln.fi.edu/cgi-bin/pursuit-beta). We have integrated this feature into many of our online resources.

- **table of contents** -- text-based, list the main components (movies, sounds, graphics, HTML files) of your online resources.
- **custom hotlists, bookmarks** -- text-based, organize and point to other Internet resources that support your online resources.
- **preview gallery** -- exhibit-based, highlight the contents of an online exhibit, less inclusive than the table of contents; a “greatest hits” concept.
- **what’s new** -- programs-based, showcase all the new exhibits, programs, events, or activities that you are supporting online.

One final thought: a double-edged aspect to this endeavor is that any resource you develop, serve, and maintain online is intimately tied to the constant evolution of hardware and software that supports it. As technical functions are added and guidelines expanded, the nature of the resources themselves will change, much like the changes witnessed in the multimedia exhibits on museum floors during the past ten years.

Plan accordingly. You don’t want to create resources that will require tremendous effort to upgrade somewhere down the road. If you create your resources based on the lowest common denominator of the HTML specification, **allowing easy viewing in Lynx, Netscape and Mosaic**, then you should be able to upgrade them to new features that come along eventually with a minimum of effort.

What strategies can be employed to insure that users will come back to your online museum (if you build it, they will come, but will they come back)?

Like the physical museum, the online museum will need to rely on new exhibits, programs, promotions, and other activities that solicit return visits via the Internet. The online museum is dynamic just like the physical museum. Planning new events and publicizing them will encourage visitors to continually seek out your online museum. Integrating a human presence may help to establish your unique online identity. Some current strategies include:

- **online docents/explainers** via home pages, listservs, newsgroups, chat rooms, email and videoconferencing support -- you could run a local listserv or newsgroup on various topics, two-week topics or continuous topics, moderated vs. unmoderated.
- **ask the expert/online mentors** via listservs, newsgroups, chat rooms, email, and videoconferencing support.
- **user guestbook** -- online user registration via CGI forms and email. This could provide the basis for seasonal emailings notifying online members of new exhibits (resources) and programs.

- **tell the president** -- user feedback via CGI forms and email to the head honcho. Visitors feel empowered when they can complain (usually) or praise their visit to your online museum. This would add a personal feel also.
- **the museum store** -- via a secure web server, generate revenue from new audiences. No small task but something to strongly consider.
- **museum memberships** -- via a secure web server, build your regional and global audiences.
- **what's new** feature via museum homepage -- organize and promote all the new, cool stuff that you're offering: online activities, contests, online Science Fair, online student exhibitions, new exhibits in physical museum (for regional audiences and those who travel), etc.
- **monthly publications** of inquiry classroom activities, bi-monthly (Internet enhanced) science stories from your local newspaper (another sponsorship opportunity).

As I mentioned earlier, the jury is still out on this front. These suggestions represent current experiments and are staff intensive, so plan accordingly. The added value of these types of online activities is that they add a strong human dimension (customer service) to your online museum -- a dimension that may ultimately make or break your online museum's ability to sustain itself.

How do we evaluate our strengths and weaknesses?

The metrics for evaluating the **quality** of online resources are still being developed within the Science Learning Network project. It is difficult to objectively measure the cognitive gains made by users in any educational arena. However, this is a necessary part of the evaluation of any resource, whether online or on the museum floor. Formative evaluation with online visitors will be critical in refining the guidelines used for continued resource development.

What other metrics exist for determining success? Museums are always big on the bottom line, the **quantity** of visitors entering our doors. In the present context of the online museum, I don't feel that Web server statistics offer an accurate view of the number of online visitors and what resources they use. They are, in fact, quite misleading. Web server statistics can be configured to show information in a variety of ways. For example, at the Franklin Institute Virtual Science Museum, we don't include accesses from internal museum staff. Some Web sites do.

Web server statistics are also misleading due to the number of "hits" (HTTP requests) that a single user can generate. For example, the current version of the Franklin Institute's homepage (http://sln.fi.edu) involves **eight separate HTTP requests**, or eight hits, when downloading the page with graphics enabled. Imagine an online visitor browsing for 10-15 minutes through additional Web pages and the total number of hits

could easily register around 50 or 60. All this means is that our server sent 50 to 60 individual files out **to a single user -- not 50 or 60 users**. So we need to create a scaling factor by which to divide all of those server hits to make them useful in measuring the number of online visitors browsing our online museum.

It may be possible to obtain a more accurate measure of the quantity of online visitors **via URLs that point to our web pages.** These may be links that others have added to their own online resources or locations on individual hotlists or bookmarks.

Strategies for Sustaining the Online Museum

The situation is still too new to have any conclusive evidence as to whether we can or cannot sustain the online museum. But being an optimist I thought I'd offer some ideas for fee for service opportunities and public relations events that may help to sustain the online museum:

- There is a significant market for teacher, adult, and youth Internet and World Wide Web training. If you are fortunate enough to have a computer resource center connected to the Internet, a logical next step is to create a program offering a series of workshops.

- Once you reach a level of expertise, become a Web server for external customers. Offer your local high schools or middle schools that chance to create their online school through your Web server.

- Create a Marketing and PR Plan in order to build and sustain your online audience. This would include regular notices (advertising) to appropriate newsgroups, listservs, and registered users of your online resources of new things to come back to and explore and buy. The issue here is what will the online community support in terms of non-profit organizations advertising via the Internet? Many newsgroups and listserv members are vehemently against any sort of blatant for profit advertising. What can we do to solicit their support of online museums?

- Sell sponsorships for your web site. Explore the potentials for online advertising opportunities rather than charging a fee for service to online members and visitors. You'll notice that the Franklin Institute Science Museum Online has a corporate sponsor acknowledged on the bottom of its home page (http://sln.fi.edu).

- Integrate volunteers, high school interns, and co-ops into your resource and program development teams. This is a great source of hungry talent to get involved with developing new online resources and programs.

- How can the online museum help to foster the growth of regional audiences? Explore the potential of registering users, via forms and email, who access your home page for inclusion in an online membership database. This could form the basis for special emailings on new online exhibits and programs. Online members could also be afforded the usual museum membership perks (discounts to the physical museum, store discounts, reduced admission to omnimax films, etc.).

- Create online events to nurture audience-building. For example, have a contest for the best online exhibit to celebrate the 50th anniversary of Eniac and Association of Computing Machinery (in 1996). Establish criteria and give away prizes (that you get a sponsor to donate). Have students do a project on the next fifty years in computing and put it online. The sky's the limit here.

- Foster partnerships within your regional community and represent them online. Being able to use a big name (like the New York Times) helps to increase the value of your online resources. A good example of this is the Franklin Institute's relationship with its local newspaper, the Philadelphia Inquirer. We publish a story, twice a month, from the weekly Science & Health section of the newspaper that is integrated with activities and other relevant Internet resources (http://sln.fi.edu/tfi/publications/inquirer/inq.html).

- Create an online host, a full-time ambassador who gives a human feel to your users. Integrate this personality with your mailings, user registration database responses, notices of museum store holiday sales, etc., to add a strong human dimension to your online museum.

Summary

This paper has focused on the processes of designing, implementing, and using local museum infrastructure to facilitate the creation and viability of online museums. Much has been said about the World Wide Web and its potential impact upon the realization of online museums. The Internet however, consists of a variety of standards and protocols of which the Web is but one subset. The other Internet components -- email, newsgroups and listservs, ftp, gopher, telnet, search engines, etc. -- are all part and parcel of the evolving landscape in which online museums exist and play a very important developmental role.

We have arrived at a wonderful moment in the history of telecommunications and museums. It is a time when anything seems possible, given adequate time, resources, and ideas. The Internet holds the promise of providing museums with an onramp to the Information Superhighway. Will we find dirt roads populated with potholes and road-kill or will we find a new means to extend our mission-based activities to the online world?

This is not a time to listen to the naysayers, but a time for innovation, experimentation, and steadfast forward motion. There are many challenges that lie ahead. Whether the promise that the Internet begins to deliver to museums is indeed a dessert topping, a floor wax, or both still remains to be seen. It is up to us to write those chapters. I know what I'll be doing, what about you?

Appendix A -- The Science Learning Network

This exciting and innovative project would not be possible without the dedicated effort of a large group of individuals. At the Franklin Institute Science Museum, Philadelphia, PA, the following people have been instrumental in designing and implementing the project:

Dr. Karen Goldstein -- Executive Vice President, Finance and Administration (karen@fi.edu)
Dr. Carol Parssinen -- Vice President, Education and Programs (cparss@fi.edu)
Dr. Wayne Ransom -- Executive Director, Education and Programs (wransom@fi.edu)
Dr. Paul Helfrich -- Director, Interactive Information Systems (helfrich@fi.edu)
Steve Baumann -- Science Learning Network Project Director (baumann@fi.edu)
Karen Elinich -- Resource Researcher and Developer (kelinich@fi.edu)
Kurt Starsinic -- Information Systems Specialist (Webmaster -- kstar@fi.edu)
Sean Casey -- Multimedia Designer (scasey@fi.edu)
Marty Hoban -- Network Resource Center Director (toons@fi.edu)
Robert Kuss -- Information Systems Specialist (System Administrator -- rkuss@fi.edu)
Michael Moulton -- Information Systems Specialist (moulton@fi.edu)

The project directors at the SLN museum partners have also been instrumental in helping to design and implement the project in their respective sites. They are:

Dr. Robert Semper -- Science Learning Network Project Director, Exploratorium, San Francisco, CA (rob_semper@exploratorium.edu)
Dr. Judy Brown -- Science Learning Network Project Director, Miami Museum of Science, Miami, FL (museum7@gate.net)
Marion Rice -- Science Learning Network Project Director, Oregon Museum of Science and Industry, Portland OR (marion_rice@omsi.edu)
David Gibbons -- Science Learning Network Project Director, Museum of Science, Boston, MA dgibbons@k12.oit.umass.edu)
Natalie Rusk -- Science Learning Network Project Director, Science Museum of Minnesota, St. Paul, MN (nrusk@sci.mus.us)

Unisys Corporation, Blue Bell, PA, has provided technical, conceptual and financial support for this project. The following have been instrumental in the design and implementation of the SLN project:

David Curry, Vice President, Corporate Public Affairs (currydav@po7.bb.unisys.com)
Alicia Egan, Senior Public Affairs Representative (egan@po7.bb.unisys.com)

Appendix A -- The Science Learning Network (cont.)

The National Science Foundation has provided generous support for this project. Our program officer there is:

Dr. Arthur St. George (astgeorg@nsf.gov)

References

Bennett, Scott, *The Copyright Challenge: Strengthening the Public Interest in the Digital Age*, Library Journal, Vol. 119, No. 19, pp. 34-37, November 15, 1994.

Bernstein, Susan, Huntley, Martin, Newman, Denis, *Toward Universal Access to Math and Science Resources (Phase 1 of a National School Network Testbed, Progress Report)*, Bolt, Barenek, and Newman Inc., Cambridge, MA, 1993.

Bernstein, Susan, Huntley, Martin, Newman, Denis, *Toward Participation in the NII (Phase 2 of a National School Network Testbed)*, Bolt, Barenek, and Newman Inc., Cambridge, MA, 1994.

Calcari, Susan, *K-12 on the Internet*, NSF Network News, September, October Vol. 1, No. 4, The InterNIC, 1994.

Falk, John H., Dierking, Lynn D., *The Museum Experience*, Whalesback Books, Washington, D.C., 1992.

Henriquez, Andres, Honey, Margaret, *Telecommunications and K-12 Educators: Findings from a National Survey*, Center for Technology in Education, Bank Street College of Education, 1993.

Hunter, Beverly, Goldberg, Bruce, *Learning and Teaching in 2004: The BIG DIG*, paper presented to the Congress of the United States, Office of Technology Assessment, Study of Teachers and Technology, Bolt, Barenek, and Newman, Cambridge, MA, December 5, 1994.

Hunter, Beverly, *Linking for Learning: Computer-and-Communications Network Support for Nationwide Innovation in Education*, Journal of Science Education and Technology, Vol. 1, No. 1, pp. 23-34, 1992.

Kay, Alan C., *Computers, Networks, and Education*, Scientific American, September, pp. 138-148, 1991.

Krol, Ed, *The Whole Internet User's Guide & Catalog*, O'Reilly & Associates, Sebastopol, CA, Special Edition, August 1994.

McPartland, Gail, *Evaluating Internet Resources*, NSF Network News, September, October Vol. 1, No. 4, The InterNIC, 1994.

References (cont.)

Nelson, Ted, *Computer Lib, Dream Machines*, Microsoft Press, Redmond, Washington, Revised Edition 1987.

NTIA, *The National Information Infrastructure: Agenda for Action*, Department of Commerce, Washington, D.C., 1993.

Office of Educational Research and Improvement, *Using Technology to Support Education Reform*, OERI, Washington, D.C., 1993.

Park, Innwoo, Hannfin, Michael J., *Interactive Multimedia Design*, Educational Technology Research and Development, Vol. 41, No. 3, pp. 67-81, 1993.

Richard, Eric, *Anatomy of the World-Wide Web*, Internet World, Mecklermedia, pp. 28-30, April 1995.

Risher, Carol A., & Gasaway, Laura N., *The Great Copyright Debate*, Library Journal, Vol. 119, No. 15, pp. 34-37, September 15, 1994.

Ruopp, Richard, *LAbNet: Toward a Community of Practice*, Journal of Science Education and Technology, Vol. 2, No. 1, pp. 305-319, 1993.

Sadavage, Gary, *A Framework for Analyzing the Alternative Methodologies for Investigating the Effectiveness of Hypermedia*, The Arachnet Electronic Journal on Virtual Culture, Vol. 2, Issue 4, pp. 1-16, September 27, 1994.

Serrell, Beverly, Raphling, Britt, *Computers on the Exhibit Floor*, Curator, American Museum of Natural History, pp. 181-188, September, 1992.

Wiggins, Richard W., *Webolution*, Internet World, Mecklermedia, pp. 32-38, April 1995.
