

Cyberinfrastructure: opportunities for connections and collaboration

Joan K. Lippincott
Associate Executive Director
Coalition for Networked Information
joan@cni.org

Abstract:

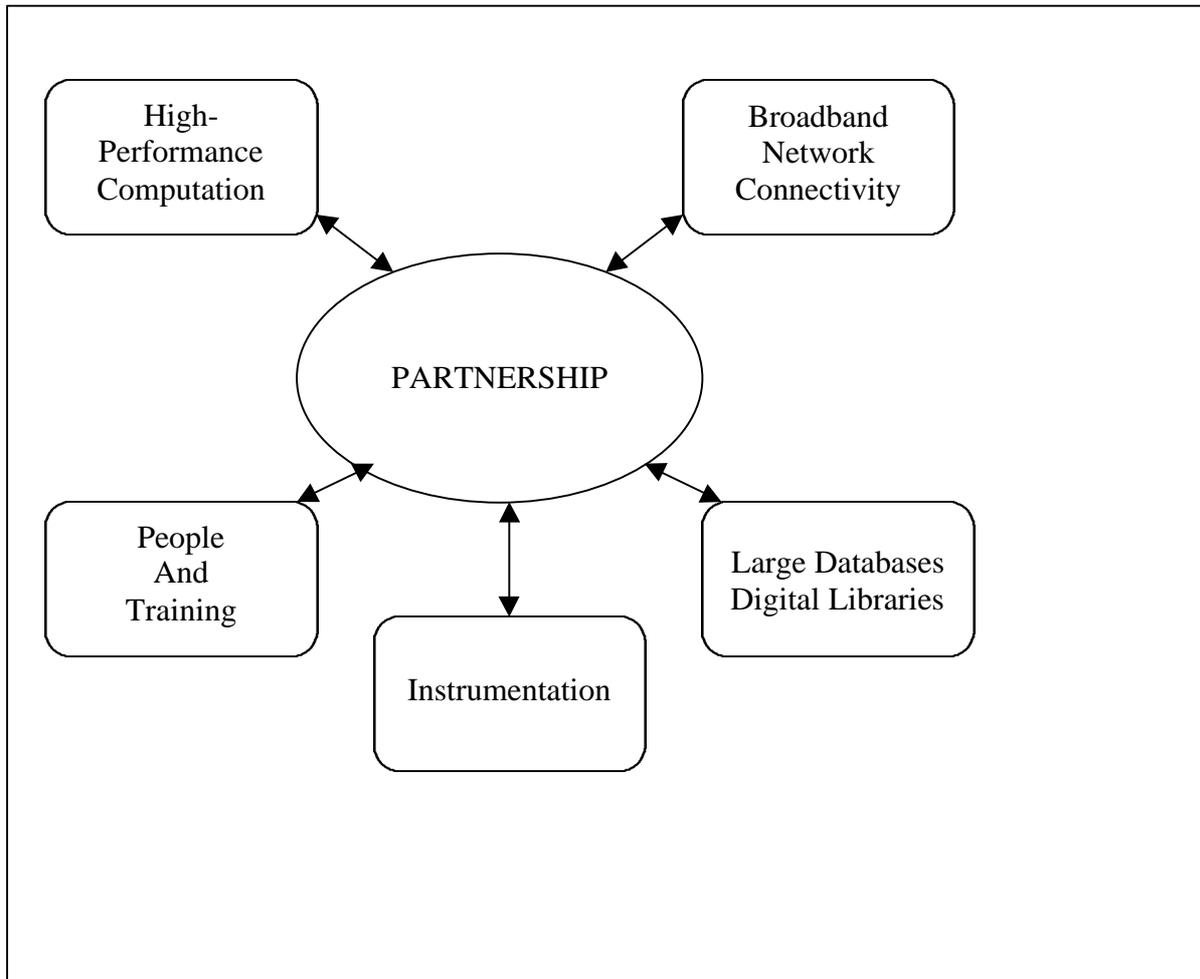
This paper explores the concepts of envisioning and building a cyberinfrastructure, a framework for developing interrelationships between high performance computing, networking, digital libraries, and people. The focus is on the new types of user services that libraries might create and offer and on the broad range of content that can be part of digital libraries. The important role of establishing partnerships and collaborations to build the components of the cyberinfrastructure is emphasized.

Introduction

As information professionals, we are building a new information infrastructure, a cyberinfrastructure, which will enable us to meet the needs of the information age. It is taking shape quickly but not always with a clear understanding of its form. Many sectors are involved in the building of the cyberinfrastructure – technology companies, telecommunications providers, universities, libraries, publishers, scholarly societies, governments, and others. Information professionals, including librarians, information technologists, instructional technologists, and multi-media specialists, have key roles to play in developing the cyberinfrastructure. However, often we feel like we are groping in the dark as we focus on developing or understanding various components of the cyberinfrastructure. In what direction will the technology move? What will develop in the ownership and control of scholarly communication? How will teaching and learning change in the networked society? It is important that we have a vision of the information infrastructure that we, as professionals, wish to create for our users and that encompasses and embraces the Internet and digital information resources. We need to develop a mental model of the information infrastructure that we are building for users.

An officer at the US National Science Foundation coined the term “cyberinfrastructure” to denote the interrelationships among a number of elements in the networked environment that serve scientists using large-scale computing resources. (Berman, 2001) Those elements include the integration into a coherent entity of high-performance computation, broadband network connectivity, information management (termed ‘large databases/digital libraries’ in the model), people and training, and access to remote instrumentation and visualization. A cyberinfrastructure both unites widely distributed resources and identifies the interrelationships among components. As seen in this diagram, the cyberinfrastructure revolves around partnership arrangements among the components.

**FIGURE 1
CYBERINFRASTRUCTURE**



(Adapted from Berman, 2001)

This paper will explore some of the advances in networking and networked information that have an impact on libraries and information management. The emphasis will be on new directions and trends in scholarly information production and management and the links to user communities. In addition, partnership among professional communities, between the commercial and educational sectors, and between users and information professionals will be described and explored. Information professionals need to build in partnership with their user communities, a cyberinfrastructure that will meet each community's needs. They need to break away from the constraints of a library-centric model and explore an environment where information exists in distributed sites and in many formats. The traditional realms of expertise of librarians remain relevant in the cyberinfrastructure, particularly in those components that relate to information management, people, and training. The identification of appropriate information resources, the mechanisms for searching for relevant content, and the frameworks for organizing information for personal use are all challenges to be addressed in the new age of cyberinfrastructure. Librarians and information professionals have much to contribute to the building of new frameworks for identifying, accessing, and managing content.

Building partnerships

The cyberinfrastructure model (Figure 1) establishes partnerships as the focal point of the emerging information environment. Librarians and information professionals are well versed in working in internal organizational teams and are among the best representatives of inter-institutional collaboration in universities. For example, the inter-library loan structures that libraries have developed are often the best examples of inter-institutional collaboration that can be demonstrated among universities. However, the involvement of librarians in collaborations beyond the library community is more limited. Whether on a campus of a higher education institution, in the government, or with community agencies, libraries have had less success in building partnership relationships, although some examples exist.

The Coalition for Networked Information (CNI)

Promoting collaboration among individuals, professional groups, institutions and companies is a key mission of my organization, the Coalition for Networked Information (CNI) which was founded in 1990. The organization itself is a collaboration between a library association – the Association of Research Libraries (ARL) – and a higher education computing association, EDUCAUSE (formerly Educom and CAUSE) (Lippincott, 1998). If you think back to 1990, you may recall that at that time, the Internet was the purview of the government and some scientists in major research universities. The Internet was used primarily for access to supercomputers that enabled researchers to carry out large computational projects and for communication among researchers, primarily by e-mail. Information technologists in some of the large research universities were among the builders of the Internet and could see that its capabilities went beyond the limited applications of its early deployment. In particular, they imagined that the Internet could be used to develop large, distributed digital libraries that could be shared among institutions. However, they knew that they lacked the expertise to work with that type of content. They reached out to the library community to work in partnership with them. The library community, by 1990, had decades of experience in working with electronic information, primarily in bibliographic databases, and had years of experience with proprietary networks such as OCLC. However, in 1990, very few librarians had experience with the Internet. They were eager to work with information technologists who could help them understand the capabilities of the new technology and could help them build new information environments for their users.

Now, more than ten years later, CNI is continuing to promote collaboration among our members and beyond. In many of our projects in such areas as university presses, new learning communities, assessment of networked environments, and collaborative facilities, we have promoted the use of cross-sector institutional teams, comprised of individuals from a variety of appropriate units on campus, to formulate and implement networked information projects. Beyond the campus, we promote collaborations between universities and scholarly societies and universities and commercial partners. Unlike most organizations with higher education institutions as their base, CNI has only one membership category for all types of organizations, institutions, and companies. Therefore, technology companies, telecommunications providers, and publishers join CNI on the same basis as higher education institutions. We believe that to advance and accelerate developments in networked information, it takes a richer relationship of partnership, beyond that of seller and buyer, to make progress. CNI was a catalyst in instigating many early electronic journal projects that were developed as partnerships between commercial publishers and higher education.

Collaboration and partnerships

I have used the terms collaboration and partnership interchangeably, as that is how they are used in the organizational behavior and management literature. However, in common parlance, the words “partnership” and “collaboration” often are used to describe relationships that are more appropriately described as “exchange” relationships, such as the relationship between a buyer and seller (Kanter, 1994). For example, a library might describe a relationship where the computing center on campus manages the hardware and software for the OPAC as a collaboration, when in fact it is an “exchange” relationship. In an exchange relationship, one party gives resources, such as money, to another party to accomplish a set of objectives. The party pays the implementer to carry out the project according to the goals of buyer of services. The seller of services may advise on strategies and options, but the buyer of services makes decisions based on its own mission and goals.

In contrast, in a genuine partnership or collaboration, the parties must develop a shared mission and shared goals. They need to have a common vision of the end point of their project or of the shape and dimensions of what they are developing. To arrive at that point, they need to develop a shared vocabulary, so that their communication is not compromised by misunderstandings due to jargon that is used differently in separate professional fields. For example, CNI has found in its collaborative work with electronic records managers and information technologists, that the professions use the term “archive” in very different ways, and a session in which each group describes how it uses certain terminology is very useful at the beginning of a project (Bernbom, 1999). Collaborative groups must come to an understanding of a method by which the work will be done, one that respects the traditions of each group represented. And finally, and perhaps most important, they need to have a genuine appreciation for the fact that the different skills and perspectives that are supplied by the individuals of the various professional groups, are positive aspects of the collaboration and not occasions for stereotyping the thoughts and actions of the other groups (Kanter, 1994; Katzenbach and Smith, 1993). Therefore, the genuine partnerships that tie together the various elements of the cyberinfrastructure are not platitudes but are symbols of a process whereby the various groups that build the cyberinfrastructure come to know each other, appreciate the skills that each brings to the project, and work together towards a common goal.

Advances in technology and networks

The changes in technology in the past decade have been truly astonishing, and the scope for building new information services and new ways of representing content seem unlimited. With increased availability of broadband communications at institutions and with high performance computing available at many universities, a range of applications involving information are being developed that take advantage of the system capabilities. These include environmental models that link disparate data sets and produce maps and diagrams that demonstrate the changes in a geographic area, telemedicine applications in which detailed images taken in a rural area can be shared with a major medical center to facilitate diagnosis and treatment, and virtual environments where researchers can explore spaces that they create using various parameters. While this paper will not focus on the technology components of the cyberinfrastructure, it is important that all information professionals keep abreast of technology trends and that they try to determine the opportunities that they present for the development of new types of content and services. The rapidity of developments also underscores the need for collaborations among groups such as librarians and information

technologists, since no professional group can develop the expertise needed in every area appropriate to the development of network-based projects. We have both the challenge and the responsibility to think in very broad terms about the use of information and the types of systems that can be built to facilitate access to and management of various types of information.

The Shape of user services

The cyberinfrastructure model groups “people and training” as one of its components; this element represents a number of activities that libraries and computer centers describe as user services, user support, instruction, and training. While most of us would agree that librarians and other information professionals have the knowledge and skills to assist users in the academic and public communities with their information needs, and that libraries can provide many useful resources to their constituencies, an increasing number of information-seekers are bypassing the library or circumventing the use of traditional print resources. Many leading universities report that their statistics of in-person reference transactions are down. (Saunders, 2001) This trend may continue as universities matriculate increasingly Internet-savvy young adults who are already using the Internet extensively in their secondary education. A study by the Pew Internet and American Life Project reports that 71% of middle school and high school students with Internet access rely on electronic resources the most in completing a project as compared to 24% who said they relied on the library the most (Lenhart, 2001).

While many librarians wholeheartedly embrace the Internet, some have a decidedly ambivalent attitude towards it. One concern is that students who rely solely on information from the Internet will have inferior results to those that would have been achieved through library use. Another common concern is that students need to know how to use *all* information resources, not just those on the Internet, and that their work will be incomplete without thorough consultation of a range of materials, including print books, encyclopedias, bibliographic databases, journal abstract services, websites, and online documents. While I agree that some information on the Internet is not useful and may be unreliable, I believe that many librarians may be underestimating the amount of freely available, high quality information on the Internet that is available from government sources, non-profit associations, universities, community groups, and others. It is not that librarians are unaware that such resources exist, it is that some seem concerned that without professional assistance, their user community will find disreputable sites and not those that offer high quality information.

The viewpoint that students need to understand the full range of information resources is something that I agree with, in principle. I believe that as part of their education, students should become information literate, and that their curriculum should prepare them for a lifelong need to locate, access, evaluate, use, and manage information. However, I believe that this should be integrated into students’ education over the long term and not made a requirement of each and every assignment involving information resources.

I believe that we need a new approach to serving students in the networked environment, one that embeds information literacy skills into the curriculum but recognizes that for many of their needs, students can find entirely appropriate full text resources on the Internet that may have no relationship to ownership by the library or access from the library’s catalog or homepage. If the library wants to serve this increasingly large group of technology savvy students, we need to recognize that many of them have a style of information-seeking that

may not conform to the ways in which library's have traditionally organized and managed information. These students

- Want relevant information, not a citation to the information
- Do not generally need to do an exhaustive search
- Like to browse or surf; precision of search is not always their goal
- Prefer freedom to control
- Multi-task and use multiple windows; they are not linear
- Use course management systems for some of their classes
- Need information from a variety of locations and at all times of the day

We are moving into an environment that is currently a hybrid environment and that will likely remain so for some time to come. The library organization will continue to have great importance for some parts of the higher education community but may have decreasing importance for some sectors.

How can we develop services that take into account the needs of a new group of users? We need to build an organization that moves in a number of new directions (Figure 2).

**FIGURE 2
DIRECTIONS FOR USER SERVICES**

From	To
Site-based	Cyberspace
Library-focused	User-focused
Librarians as experts	Librarians as co-explorers
Generic content and services	Customized content and services
Highly organized structures	Experiential environments
Libraries/classrooms	Information commons/learning centers

Many libraries are offering online reference service for their users, and some large, multi-library projects are emerging to enable access to professional reference librarians in a 24X7 environment. These projects take into account the need to provide services to users in cyberspace and not just site-based contexts. Whether the users are students in dormitory rooms or researchers from another country, online reference service is a useful institutional response to the needs of users. While most online reference services are e-mail or web form based, some experimentation with online chat software is beginning. For libraries serving primarily a student clientele, this seems a fruitful avenue for experimentation since students increasingly use instant messaging software as part of their daily communication pattern.

Libraries can also take the lead in developing structures that facilitate identification of scholarly or reputable information sources; the Association of Research Libraries is discussing a project of this type as are other organizations (Campbell, 2000). It is important that such projects aim to develop improved search engines that allow more sophisticated

searches while keeping search mechanisms transparent. There also needs to be better integration of library resources and Internet resources that are not licensed or owned by the library.

Librarians take pride in their skills and some have been known to hang back from implementing new services until they become experts at them. In the Internet environment, the culture rewards experimentation rather than mastery of skills. Librarians can be co-explorers with their students rather than the expert. In the teaching and training environment, this can also be the case. A recent article described new types of involvement librarians are engaging in at a small college and noted of one librarian, "She also had the rare opportunity to interact with students in a different power dynamic – on this day, the students taught the librarian in a biology laboratory instead of learning about research databases in the library. During these interactions, the students were very candid about their research needs and library usage patterns" (Furlong, 2001).). Kanter (2001) describes the need for "reverse mentoring" in the current technology environment, where the young teach the old. Students can be part of teams creating elements of the cyberinfrastructure and can contribute their skills as they learn from other team members.

Organizing information and providing access mechanisms is at the core of the library's mission. However, librarians generally define the nature and shape of services, which are offered on an equitable basis to all users. In the Internet environment, customized and personalized services are more common. Librarians can play a key institutional role in developing or selecting information systems that will allow personalization and customization. For example, some libraries are implementing "My Library" software that enables users to create web pages that link to their favorite resources and updates them with new items of interest (MyLibrary@NCState). As one report states, "User satisfaction is the ultimate aim of personalization" (Bonett, 2001). As such systems develop, there is a need for detailed assessments of user satisfaction such as the evaluation of the HeadLine Personal Information Environment by users at three British universities (Gambles, 2001). The evaluation results, which were based on a low response level, revealed that use was infrequent, training was needed for successful use, and satisfaction was mixed. System developers should not be discouraged by such responses but should seek to understand better user needs and behavior.

Students may find that access to information resources through course management systems such as Blackboard™ and WebCT™ is a more convenient way to access materials than through a separate library site. Partnerships between faculty and librarians and librarians and information technologists can facilitate the integration of library resources into course management systems.

In many ways, librarians and information system developers have been attempting to build tools and services for Internet information resources that are analogous to those in the existing library environment. For example, creating catalogs and databases are traditional library "answers" to access to information. We need to be open to new approaches in some cases. For example, in a study by the Colorado Digitization project, a partnership among libraries, museums, and historical societies, users stated a clear preference for information presented in an "exhibit" format to information presented in a "database" format. In the exhibit format, users liked that the facts are right there, that they don't have to search, and that pictures told the story. They also found it more organized and easier to find information as compared to the database format, which they found takes too long. They stated that they got bored reading directions on how to use databases (Bishoff, 2001).

Other lessons can be drawn from the way some commercial services provide access to information such as Amazon.com™. However, sometimes those types of systems conflict with the values inherent in library systems. For example, personalization services require institutions to keep information on the habits of individuals, a tactic that libraries have been trying to avoid for privacy reasons (Lynch, 2001). In the academic sector, instructional programs such as the University of Texas at Austin TILT, provide a playful introduction to information literacy, incorporating some of the game techniques that are so familiar to many undergraduate students (TILT, 2001).

Collaborative facilities are another way that services can be delivered to users in a coordinated way. Rather than focusing on the traditional library departmental layout of circulation, reference, etc., new collaborative spaces such as information commons and learning centers are being developed and staffed in partnerships between libraries, computing, faculty and multi-media personnel. A facility such as the Percy Baxter Collaborative Learning Centre at the University of Melbourne is an example of these projects that provide user-centered spaces (Robertson and Sullivan, 2000).

While these comments have focused largely on serving undergraduate students or users in the general population, there are equally serious needs for the development of new information services for information-intensive users such as faculty, graduate students, and, independent researchers. In many cases, to adequately serve the advanced information needs of these users requires subject expertise in the field, an in-depth understanding of technology, and the ability to help design and build information management systems or digital information resources. Working with faculty and other researchers on the development of digital content is an emerging role for information professionals, and content issues will be discussed in the next section of this paper.

Directions for content

Stevan Harnad, an early pioneer in understanding the capabilities of the Internet for scholarly communication, writes, “It is easy to state what would be the ideal online resource for scholars and scientists: all research papers in all fields, systematically interconnected, effortlessly accessible and rationally navigable from any researcher’s desk worldwide” (Harnad, 2000).

Harnad’s vision is only one component of the content dimension of the cyberinfrastructure. An online resource of research papers would be a key component of a digital library in some fields, particularly in the social sciences, but in other fields, different types of information resources may be of greater significance to researchers. For example, in the humanities, digitized manuscript collections or collections of digital images may be of critical importance for some scholars; in the sciences, large databases of all types of information could be the primary information resource. Librarians and information professionals have worked with faculty and researchers for years in assisting them with online systems. As we engage the Internet environment, we must keep our imaginations alive and envision new ways of organizing, managing, interconnecting, and representing information that will enrich scholarship. At the same time, we must work to develop and employ standards that encourage interoperability of a multitude of information resources. Through collaborative projects between librarians, faculty, scholarly societies, publishers, and information technologists, we need to establish a shared mission for the creation of genuine digital libraries.

There is growing concern among government agencies, funders, and library leaders that the current crop of digitization projects is not developing into a coherent whole that could be described as a digital library. Disparate pieces of collections, often digitized because of the availability of specially designated grant funds, are not necessarily of value to scholars because of their limited content. We need to forge agreements that build coherent digital collections in various subject areas and in countries. This will take a great deal of planning, a willingness to compromise, and an interest in finding a way to develop shared goals among institutions.

As we build digital libraries, we need to have a broad view of the nature of their contents, not limiting our vision to digital forms of print artifacts. Some of the characteristics of the emerging content environment are provided in Figure 3 and contrasted with the traditional print environment.

**FIGURE 3
DIRECTIONS FOR CONTENT**

From	To
Print	Multi-media
Static	Changing
Standard formats	Hypertexts; composite formats
Collections	Portals
Commercial publication	Collaborative publishing

Just a decade ago, if one wished to find a compendium of information on the classical world, covering history, art, language, and culture, one might have turned to a solid print resource such as a specialized encyclopedia. Now we have the Perseus Digital Library, a multi-media website that includes a Classics collection. A scholarly resource of high quality, Perseus includes digitized ancient and secondary texts, images of art objects and coins, maps, and site plans. It is freely available on the network and contains invaluable materials for students and researchers. The Perseus Digital Library lists a wide variety of collaborators on its website, including US and European higher education institutions, university archives, a scholarly society, and a museum. All of these sectors contribute to the project, and Perseus contributes to the mission and projects of its collaborators (Perseus, 2001). Many campuses and communities have or will have scholars who wish to create digital information resources. Information professionals need to be capable of providing advice to these projects on a range of issues, including intellectual property rights, metadata, document and image format standards, and long-term preservation.

One of the most exciting characteristics of digital objects is their ability to keep changing, adding new information, correcting errors, linking to relevant resources, and adding commentary from others. These objects present special challenges to librarians, who need to develop policies and procedures for maintaining digital content over the longterm. The US Library of Congress is doing some interesting work on capturing websites of significant events on a frequent basis as an experiment in how to manage information that changes rapidly. Their efforts include websites of the Presidential election of 2000 and the tragic events of September 11.

Text-based documents are still a mainstay of scholarly communication, but compound documents or texts supplemented with other types of content are being developed. The technologies available today enable a researcher to publish a dataset along with an article on demographics, or an image collection along with an article on the pathology of a particular disease. Projects such as the Networked Digital Library of Theses and Dissertations (NDLTD) encourage students to publish theses and dissertations using the range of technology capabilities available (NDLTD, 2001) and those students will produce the scholarly literature of the next generation. Information professionals can become partners in the production of new types of content, advising the authors, developing an institutional website that can accommodate the publications, and making plans for the long-term availability of at least some of the materials.

Bibliographers in libraries have made their careers building collections of materials. In the distributed Internet environment, the trend is towards building portals or subject gateways that provide access to subject collections that may be owned or licensed by the library or that may be freely available on the Internet. Cooperative collection development has had a mixed history in libraries and so far, cooperative development of information resource portals for academe has been much discussed but not widely implemented, at least in the US. In the UK, the Arts and Humanities Data Service and other initiatives have provided a model for others to emulate.

One of the most compelling movements in scholarly communication is the growing interest among researchers in publishing their work in a way that will be freely available on the net. The pioneers in this development were the physicists who contributed to the development of an e-print archive hosted at Los Alamos labs. Preprint initiatives in various academic fields attempted to follow the lead of the physicists, but not all succeeded. The motivation for such projects is the quick dissemination of the latest research to members of a particular field, without charge and without restriction. The preprint services are not meant to substitute for the publication of a final product (an article) in a journal, particularly as that process is essential in the reward system of academe. The projects intend to provide the most current work quickly and to provide easy mechanisms for communication among specialists. Variations on the subject archive are the institutional archive, which attempts to provide a framework for publications by members of a university or other institution, and the self-archive, in which the researcher maintains the right to post his work on his own or an institutional website even if a publisher holds the rights to the material in other formats and venues.

SPARC: The Scholarly Publishing and Academic Resources Coalition established by the Association of Research Libraries, promotes collaboration between universities and scholarly societies. They work together to develop electronic journals that serve their fields at a modest cost and in some cases provide competition to more costly journals produced by the commercial sector. Other associations, universities, and publishers are developing publishing initiatives such as a recently announced project to develop digital library initiatives between Johns Hopkins University Press and Oxford University.

Clearly, the scholarly communication environment is in flux. We need to work collaboratively to create digital libraries that will best serve our users, meaning that they bring together collections of value to teaching and research, they are structured to facilitate searching and discovery, they provide a rich mix of formats that takes advantage of new developments in technology, and they are available cost-effectively to our users.

Conclusion

The notion of a cyberinfrastructure is useful since it focuses on the many aspects that are necessary to build an information environment in the Internet society. The networks and computers are not sufficient to advance the goals of society in general or higher education in particular. We need people, both users and information professionals, to create and use services and we need to create a rich set of digital content that enhances the capability of users to learn and to do research. As information professionals, we should develop content and services for specific user groups in concert with them and with a full understanding of their needs. We must develop a shared vision of the future digital library and associated services with our user community and in the broad context of our peers. We need to tailor services to use the new medium and the user styles that are evolving, to best advantage, and not be limited to existing frameworks and structures. Developing the cyberinfrastructure requires many types of expertise and skills from many groups and individuals. Collaboration is essential to its success.

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