BRIDGING THE GAP:

A CONCEPTUAL MODEL OF THE ACCESS OF DIGITAL LIBRARIES

Bing Pan[1*], Ph.D. (panb@cofc.edu)
Helene Hembrooke[2], Ph.D. (hah4@cornell.edu)
Geri Gay[2], Ph.D., Professor and Director (gkg1@cornell.edu)
Gerald C. Gonsalves[1], Ph.D. (gonsalvesg@cofc.edu)

1. School of Business and Economics
College of Charleston
66 George Street
Charleston, SC 29424
Phone: 1-843-953-2025
Fax: 1-843-953-5697

2. Human-Computer Interaction Group
Information Science
Cornell University
Information Science
301 College Avenue
Ithaca, NY 14850
Phone: 1-607-255-5530
Fax: 1-607-255-8312

* Corresponding Author

BRIDGING THE GAP:

A CONCEPTUAL MODEL OF THE ACCESS OF DIGITAL LIBRARIES

ABSTRACT

This paper proposes a general conceptual model for the access of digital libraries based on relevant research in information retrieval, information seeking and foraging, and activity based design theory. The authors reveal that a gap exists in current digital library design practices in which a digital library is disconnected from its targeted user community. Search engines have disintermediated many digital library interfaces and their related evaluation and usability efforts. Many digital libraries are losing their users since users have learned how to use search engines to access open Web content of collective knowledge of a wider mass instead of a specific digital library. Accordingly the authors promote a marketing orientation of digital library design and argue that we should sell the digital library in users' familiar information environment.

1. Introduction

Many digital libraries have been developed over the past decade (Borgman, 2002), and the investment in designing digital libraries (DLs) in Europe and the United States has been significant. In the U.S. alone, federal funding from 1994 including the National Science Digital Library (NSDL), the Digital Library Initiative (DLI-I and DLI-II) and Digital Library for Earth System Education (DLESE) has accumulated to a large amount of around $240 million (Fox & Urs, 2002) (Table 1). However, many existing digital libraries are not being used in the manner that they were originally intended. Consider the following three scenarios of digital library uses:

Table 1. Federal Support for Digital Library Projects in the U.S.*

Time	Project	Investment in million $
1994-1998	DLI 1	30
1999	DLI 2	55
2000	NSDL	13
2001	NSDL	25
2002	NSDL	59
2003	DLESE	1.2
2003	NSDL	19
2004	DLESE	0.25
2004	NSDL	19
2005	DLESE	0.25
2005	NSDL	18
Total		239.7

* Data Source: National Science Foundation, 2002, 2004;
D.J. McArthur, personal communication, July 17, 2006

(1) An analysis of the log files from the NASA digital library indicates that a large number of

users access NASA publications not through the NASA Digital Library interface, but through

general search engines like Yahoo, Altavista, and Lycos. The abstracts and reports in the

digital library are indexable by crawlers and spiders, and the users formulate complex queries

to search through those search engines instead of accessing the collections through the digital

library's own interface (Maly, Nelson, & Zubair, 1999);

(2) Google has become a substitute for specific-purpose digital libraries, such as INSPEC

(http://www.iee.org/Publish/INSPEC/). Even though limited to open sources, Google is more

up-to-date and broader in context. The indexed sources are good enough and the documents

are always downloadable (Arms, 2000);

(3) A web log analysis of the portal of NSDL (http://www.nsdl.org) shows that most users of

NSDL are insiders (researchers and developers who are studying and building NSDL) and

outliers (researchers, evaluators and educators who are remotely related with the

development of NSDL). There are very few real users (users who are outside of the

development community) who accessed the NSDL portal with the purpose of finding answers for science, engineering, mathematics, and technology-related questions (Pan, 2003).

These examples indicate that a thorough understanding of the access issue of digital library resources is needed. Many digital library design practices still adhere to the "Build-it-and-they-will-come" philosophy originating from the information technology hype. With increasing online information sources, users have more and more choices even for a single information task. As illustrated above, the users can find a piece of information through search engines such as Google and skip the digital library interface. This substitution effect of different information sources is not well-considered in the design process of digital libraries. User studies of most digital libraries were targeted at specific interfaces without considering the rich information environment the users are situated in and the myriad competing information sources surrounding them (Bollen & Luce, 2002; Borgman, 1986; Computer Science and Telecommunications Board, 1998; Marchionini, 1992). There is a gap exists in current digital library design practices in which a digital library is disconnected from its targeted user community. Many digital libraries are losing their users; users have learned how to use search engines to access open Web content of collective knowledge of a wider mass, but not digital library content which may require more effort in locating the digital library's entry point. Thus, search engines have disintermediated many digital library interfaces and their related evaluation and usability efforts. On the other hand, some information seeking and information search literature is theoretical in nature and not able to provide any direct design guidance (Kuhlthau, 1991; Wilson, 1997).

Two limitations in the current research on digital libraries may contribute to the gap between the design of a digital library and its actual use. First, as Fox and Urs (2002) pointed out, digital library research is in desperate need of theoretical models. Without a proper theoretical model covering a broad context of information resource uses, our understanding of the real use of digital information sources is limited, and the design of digital libraries will continue to follow the "Build-it-and-they-will-come" philosophy. Second, there has been much confusion regarding the definitions of Digital Library and what types of functions a digital library should include (Borgman, 2000; Fox & Urs, 1995). According to Fox, Akscyn, Furuta, and Leggett (1995), Digital Libraries may be conceptualized as the computerization of traditional libraries, new ways to carry out functions of traditional libraries, or new types of community-based organizations and institutions (Borgman, 2000; Lucier, 1995). Different definitions reflect confusions in the understanding of the users and contribute to the difficulties and limitations of research on digital libraries.

In this paper, a holistic view of digital libraries from the user's perspective is employed. Digital libraries are viewed as different levels of collections of digital information pieces a user has access to: from general search engines like Google and Yahoo, special purpose search engines like CiteSeer (**http://citeseer.com/**), to specific collections or databases like the ACM Digital Library (**http://www.acm.org/dl/**). The whole web space could be viewed as a vast digital library and so could be a special collection of documents. These different levels of digital collections form different levels of information clusters (Pirolli & Card, 1999). Taking this definition of digital libraries and based on existing theories on information retrieval, information seeking and foraging, and activity based design theory, this paper develops a general conceptual

model of the access of digital libraries in order to identify the gap between a digital library and its targeted user community. By couching information seeking behavior in a connectionist view of the information environment, the paper then promotes a marketing orientation of digital library design, which will provide direct guidance on how to develop a digital library in terms of providing more appropriate contents, collections, and functions as well as designing its interface.

2. Theoretical Foundations

Relevant research in information retrieval, information search and foraging, and activity based design theory have revealed a complex relationship between users and their information environment. This section reviews pertinent research which informs the conceptualization of the access of digital libraries.

2.1 Information Retrieval, Information Foraging, and User's Mental Models

Research in Information Retrieval (IR) has a long tradition in clarifying how people use electronic systems to access information. However, traditional IR studies are limited because the user's cognitive states are excluded from the model. Recently, Information Retrieval research has shifted from a physical paradigm to a cognitive paradigm, and includes various contexts and user's individual differences which are beyond the system itself (Jacob & Shaw, 1998). A cognitive perspective of information retrieval argues that "any processing of information, whether perceptual or symbolic, is mediated by a system of categories or concepts which, for the information-processing device, are a model of his world." (de Mey, 1977, pp. xvi-xvii). This line of research has included works on cognitive models (Barker, 1998; Barker, van Schaik, & Hudson, 1998; Ellis, 1989; Kuhlthau, 1991), social constructionist view of knowledge

production (Tuominen, Talja, & Savolainen, 2003), user perceptions and attitudes (Belkin & Vickery, 1985; Applegate,1993; Davis, 1993), affect (Dalrymple & Zweizig, 1992), and self-efficacy (Nahl, 1996).

Information foraging theory provides a useful metaphor in explaining user's information seeking behavior (Pirolli & Card, 1999). Information searchers seek and organize information in clusters in order to minimize inter-cluster information search cost. Information clusters can be in physical (such as a stack of books on the desk) or digital forms (such as a web site containing algebra tutorials). Information searchers use proximal cues to identify important information for further exploration or consumption. The concept of "information scent" is a construct used to address how information seekers identify valuable information from the "snippets" of proximal cues (Chi, Pirolli, Chen, & Pitkow, 2001). On the Web, those proximal cues are represented by link anchors.

A user's mental model, as a general construct that represents individual differences and various layers of context of an information task, is used extensively in information search and seeking literature to explain various information search behaviors (Saracevic,1991). The user's mental model represents individual differences that include cognitive (metaphors, prior experience, domain knowledge, and perceptions of usefulness and ease of use), social (motivation, relative interests, and information need), and demographic (gender, age, cultural backgrounds, and education) variables. User's mental models are not only useful in explaining the different information sources that users choose for a specific information task under a certain

context and scenario, but also determine the navigation and information search behavior inside an information source.

Recently, Bilal has argued that an affective paradigm is necessary to advance information retrieval and seeking research and design effective information systems (Bilal, 2005). Her study revealed the influences of various affective states, such as frustration, confusion, joy, satisfaction on children's information seeking behavior (Bilal, 2005). In fact, Kelly (1963) has proposed the influences of mood on users' information access. Kuhlthau (1991) argued that attitude, and stance, will influence information seeking capability. Her six-stage information seeking model (initiation, selection, exploration, formulation, collection, and presentation) includes different prominent feelings at each stage. She also discovered that different populations of users have distinctive feelings at different stages. Wilson argued that the design of information systems should be guided by users' affective needs (Wilson, 1981). However, Belkin warned about the difficulty of building a model of affective aspects of information seeking (Belkin, 1984). The applicability of the affective state in into the design of information systems is questionable since no system has exploited affective models of users according to the authors' knowledge.

2.2 The Theory of Activity Centered Design

Activity based design theory, which incorporates multiple contexts and scenarios in the use of computers, is an approach that describes the interaction between the users and the tools that supports the goals of the interaction. Activity theory, as an extension to traditional Human-Computer Interaction theories, argues that the use, design, and evaluation of technologies are socially co-constructed and mediated by human communication and interaction. The interaction between a person and mediating tools should be positioned within a larger space of motives,

community, rules, history, culture, and other aspects of context (Gay & Hembrooke, 2004).

Activity theory is a holistic approach that integrates multiple levels of analysis on diverse and

multi-dimensional activities and various contextual features of computer-mediated

communicative practice into a coherent model of human-computer interaction (Nardi, 1996;

Engeström, Miettinen, & Punamaki, 1999). Similarly, ethnomethodology studies how people

make sense of their social world. This methodology does not assume the orderly and categorical

social reality and instead researchers should study how people make mental order from the

chaotic social world (Garfinkel, 1967).

Accordingly, in investigating the access of digital libraries, it's essential to explore and

understand the tasks, scenarios and contexts in which the information seeking is happening.

Research in information seeking (Borgman, 2000), information needs, and the use of the

Internet, confirms that the task situations and individual variables, including demographic

variables, cognitive styles, and computer experience levels, can all influence users' information

seeking experience (Hsieh-Yee, 2001).

Based on activity based design theory, this work proposes that a digital library user is

situated in a layered system of context that includes a micro system, a meso system, and a macro

system (Bronfenbrenner, 1979; Gay & Hembrooke, 2004). The micro system includes the user's

individual characteristics (domain knowledge and information search experience, skills and

expertise). The meso system refers to tasks and scenarios, and the macro system represents a

community a user belongs to. These three levels of context all influence the use of digital

libraries or electronic resources in different ways, and they all need to be taken into consideration

when designing digital libraries for a specific user community. A user's mental model reflects these three layers of contexts of an information search task and determines the outcome and experience of every information search and seeking effort.

These design and theoretical underpinnings have contributed to a shift in the way we have begun to conceptualize the problems associated with digital libraries and the ways to address them. The following is an introduction to a new model of digital library use from a user's perspective.

3. A Conceptual Model of the Access of Digital Library

A user's information environment is rich and diverse. Such diversity requires a user to access and organize information in clusters in order to reduce his or her cognitive load and inter-cluster information search cost (Pirolli & Card, 1999). These Information sources are actually information clusters at various levels. There are also different types of accessibility to these information clusters, including physical access, geographic access, intellectual access, open access, multi-lingual access and perpetual access (Coleman, 2006). This model is focusing on physical access from a user's perspective: he/she has access to many information clusters, for example, general search engines such as Google, special purpose search engines such as CiteSeer, or a university library web site. The choice of one specific type of information cluster is determined by many variables as discussed before, for example, a specific community a user belongs to, the tasks and scenarios related to the information search endeavor, the user's individual preferences and experience with certain information clusters, and perceived cost and benefit of accessing different information clusters (Ratchford, Talukdar, & Lee, 2001). In other

words, a user's micro, meso, and macro systems in which one is situated will influence those information clusters one is familiar with (Gay & Hembrooke, 2004). For example, Google.com is a popular information cluster for the indexed web space because its strong capability in retrieving authoritative results is well-accepted among its users (Brin & Page, 1998). Of course, there are many methods in controlling access to digital information which involve user right issues (Eschenfelder, 2006). Those controlling methods may add extra cognitive or financial costs to information access. All these variables will determine a user's mental model regarding his or her view on different information clusters. When faced with an information need, the user will evaluate different information clusters and make a decision to choose one for further information search.

Information clusters may have different levels. Figure 1 illustrates the relationship between a digital library, a user's information environment, and a user's mental model. A user's mental model is determined by the three layers of contexts a user is situated. In Figure 1, the dots on the bottom represent basic information nodes, for example, information node A represents a piece of information about when a particular specie of dinosaur lived. Those pieces of information are inter-connected in different ways in a hypertext environment. The second level of dots (Yahoo, Google, and NSDL) are a higher level of information clusters, which are contained in web sites, stacks of books, or a part of another individual's knowledge base. Furthermore, these levels of clusters may be further aggregated into higher levels of information clusters. For example, a meta search engine such as Dogpile for accessing multiple web sites and a reading room where several stacks of books are co-located are all higher level of information clusters.
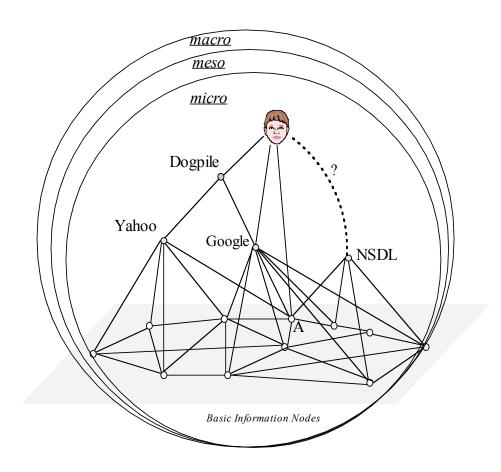
FIGURE 1. An example of information clusters

A digital library is an information cluster with the added value of structure and order (Levy, 1995). There are several information access channels to node A: users can search it from Yahoo and Google, or though a digital library, such as the portal of NSDL.org. The user can even reach that node directly if he/she bookmarks that web page if that piece of information is valuable or interesting enough. However, in most cases the user only has very few regularly-accessed information nodes, such as Dogpile and Google. If an information search task arises and a user happens to know this new information cluster (e.g. NSDL) and the user considers NSDL as an appropriate information cluster for the task, the user may take the most direct route by typing in its web address without going through search engines. In Figure 1, the user may take the route

from the user directly to NSDL.org. Next he or she searches and navigates to a specific information piece inside NSDL.org. However, after a digital library is built, the most of its target users may not know its existence; therefore, there is no linkage between his or her frequently-accessed information access clusters and the digital library interface (in Figure 1, for most users, there is no direct linkage connecting the user to NSDL). Often, the indexing of search engines (such as Google) will make the resource available when a user searches information online using one of those search engines. The users will prefer the least-effort approach by search through Google rather than remembering a new website called NSDL. This is the breakdown illustrated by the NASA digital library scenario as discussed in the Introduction section, in which the users took a more circuitous and costly route to access a piece of information.

The discussion above shows that there are two access steps related with the access of digital libraries: a user needs to search and navigate through his or her information space in order to reach a digital library interface; the user also needs to search and navigate through the digital library to reach a specific piece of information. Previous usability testing and evaluation have focused primarily on the second part of the problem which is related to interface design and information architecture, e.g. information access inside a digital library, but not the link between a digital library interface and its users. This paper proposes that the first one is closely related with the mental models of its targeted users, which represent the three layers of contexts, including the user's community and culture, cognitive style, skill and expertise of using the Internet and digital libraries as information clusters. More specifically, those layers of contexts will determine the awareness of different information sources and the utilities of those sources for a specific information task.

4. A Marketing Orientation of the Development of Digital Libraries

To bridge the gap between a digital library interface and its targeted users is similar to the introduction of a new product into a consumer market. The goal is to promote the new information cluster to its audience among its well-established competing information clusters the users are already familiar with. In marketing research literature, it is well-accepted that market orientation is essential to the success of a new product besides organizational factors and technical factors (Cooper, 1979; Cooper, 1983; Ernst, 2002). According to Kohli and Jaworski (1990), marketing orientation is "the organizationwide generation of market intelligence pertaining to current and future customer needs, dissemination of intelligence across departments, and organizationwide responsiveness to it" (Kohli & Jaworski, 1990, p. 6). In order to make new products successful, firms need to gather market information to improve their understanding of the marketplace, better satisfying their customers and gaining competitive advantages (Ernst, 2002). Similarly, in order to design a successful digital library, we need to understand the "marketplace" of information clusters and also the targeted users' information needs and information search behaviors. The marketplace is composed of those existing information clusters in the users' information environment. We need to discover the users' commonly used information clusters and their mental models of different information clusters under different tasks and scenarios. A study focusing on understanding the utilities of those information clusters in satisfying various users' information needs is essential and we should position the new digital library in this marketplace accordingly.

Most evaluation efforts of digital libraries are post-hoc in nature and targeted at the uses of a specific interface (Thong, Hong, & Tam, 2002) with a few exceptions in which the developers tried to engage the users in the process of the development of a digital library (Morse, 2002). The authors suggest that different from post-hoc evaluations and usability testing that is traditionally conducted after a digital library is built, more studies should be conducted prior to the design endeavor. Under the umbrella of layered contexts of digital library use, researchers should explore the users' mental models regarding various digital information clusters. The goal is to understand the tasks, contexts, and scenarios of different digital information cluster uses and their utilities, and provide appropriate design and marketing strategies for the new digital library we intend to design. Specifically, the following questions should be addressed in the user studies priori to the development of a digital library: What are the typical tasks and scenarios under which different digital libraries are used for information search? For the targeted user community, what types of information clusters are used contingent upon certain tasks and scenarios? What are the advantages and limitations of current information clusters in completing the tasks at hand? The answers to these questions could elucidate the competing "information products" on the market and provide the direction on the content and interface of the digital library. To accomplish this goal, it is necessary to include user study expert(s) in the development team. Also we might only need a limited number of users. According to Nielsen (2000), testing on 5 users can discover 85% of problems on average. If the digital library has distinctive user groups, testing on 3-5 users for each group might be sufficient. Similarly, great insights might be gained from interviews or surveys on a limited number of users which may not require a large budget but will produce significant implications for development direction.

In the end, the designers need to find the "niche market" of the digital library which includes collections and functions not available through existing information clusters in the target users' information environment. In other words, the information gathered from the study will inform developers of a digital library on how to best position the target digital library in the whole information environment surrounding the users. In addition, we also need to market the target digital library in the users' frequently used information clusters (such as Google) in order to foster the development of a direct link from the users' mental models to the library.

Even though the authors didn't conducted any research plan based on the proposed model, some past digital library development and research endeavors have provided evidence to support such an approach. For example, Bishop (1998) noticed that the profiling and authentication system of a digital library for the purpose of knowing the users actually created unnecessary barriers. Limited awareness of the system and authentication and registration requirements prohibited a large portion of users in adopting the digital library. Weedman (1998) also argued that users are motivated by similar marketing principles such as Return on Investment (ROI); more specifically, they evaluate the potential return of using that information system versus the time and effort needed. This is the gap discussed in this paper and corroborated the necessity of a marketing orientation approach to digital library design.

5. Conclusions and Future Research

This paper proposed a conceptual framework on the access of digital libraries. The authors argued that there is a gap between current digital library design and its targeted user community. Search engines have disintermediated many digital library interfaces; many digital libraries are losing their users to competing information sources like Google which contains open Web

16

content of collective knowledge of a wider mass. Various controlling methods will change

different types of accessibilities of digital resources and as a result change users' mental models

(Coleman, 2006; Eschenfelder, 2006). The authors promote a marketing orientation of digital

library design and promote the digital library in users' familiar information environment. It also

provides new insights on the design of digital libraries and future research in digital libraries.

The following paragraphs detail the design implications and future research directions.

The marketing orientation on digital library design proposed here has the potential to provide

the blocks for bridging the gap between a digital library interface and its targeted user

community. The development team needs to understand a general user mental model of the

various information clusters in their information environment and their advantages and

limitations, as well as why those information clusters are chosen. Thus in designing a digital

library, we can understand the competing or complementary information clusters the digital

library will face. Accordingly we can position and design a digital library with clearer goals and

sharper focus. Before undertaking any design endeavor, developers need to ask themselves, how

should we position our digital library in the information environment of targeted user

community? How should we market our digital library in order to build the information access

clusters in the users' mental models? The development team also should embrace the competing

information clusters which the users have adopted rather than alienate them. For example,

making sure the individual pieces in the digital library are indexable in search engines and users

could access them from those search engines. Even though users won't access the main

homepage, they can still reach those information nodes through other access channels. Thus, the

development should put more emphasis on building high-quality basic information nodes as well as a user-friendly homepage and structure.

To validate the conceptual model proposed here, systematic investigation of these methods with actual digital library design practices is needed. Furthermore, research on the adoption of various digital libraries will further clarify the determining factors of successful digital library design. Digital resources and their uses both evolve as a process of co-construction (Gay & Hembrooke, 2004). Thus a longitudinal study on the evolutionary relationship between users' behavior and their information environment is a promising direction. Based on existing Internet archiving endeavors such as Internet Archive (Kahle, 1997) that capture past digital resources, such efforts would be feasible and fruitful. These future research efforts could further our understanding of the uses of technologies in science and education, and provide the appropriate direction for future digital library development. This paper hopes to provide a new useful framework conceptualizing the most significant problem in digital library design.

6. Acknowledgements

REFERENCES

Applegate, R. (1993). Models of user satisfaction: understanding false positives. *RQ*, *32*, 525-539.

Arms, W.Y. (2000). Automated digital libraries: how effectively can computers be used for the skilled tasks of professional librarianship? *D-Lib Magazine, 6*. Retrieved April 10, 2003, from http://www.dlib.org/dlib/july00/arms/07arms.html.

Barker, P.G. (1998). The role of digital libraries in future educational systems. In D. Raitt Ed., *The 1998 Proceedings of Online Information*, 301-310. Oxford: Learned Information Ltd.

Barker, P.G., van Schaik, P., & Hudson, S.R.G. (1998). Mental models and lifelong learning. *Innovations in Education and Training International*, *35*, 310-318.

Belkin, N.J. (1984). Cognitive models and information transfer. *Social Science Information Studies*, 4: 111-130.

Belkin, N.J., & Vickery, A. (1985). *Interaction in information systems: a review of research from document retrieval to knowledge-based systems*. London, UK: British Library.

Bilal, D. (2005). Children's information seeking and the design of digital interfaces in the affective paradigm. *Library Trends*, 54(2): 197-208.

Bishop, A.P. (1998). *The Journal of Electronic Publishing, 4* (2). Retrieved February 13, 2006, from http://www.press.umich.edu/jep/04-02/bishop.html.

Bollen, J., & Luce, R. (2002). Evaluation of digital library impact and user communities by analysis of usage patterns. *D-Lib Magazine*, *8*. Retrieved April 10, 2003, from http://www.dlib.org/dlib/june02/bollen/06bollen.html.

19

Borgman, C.L. (1986). The user's mental model of an information retrieval system: an experiment on a prototype online catalog. *International Journal of Human-Machine Studies*, *24*, 47-64.

Borgman, C.L. (2000). *From Gutenberg to the global information infrastructure: access to information in the networked world*. Cambridge: MIT Press.

Borgman, C.L. (2002). Challenges in building digital libraries for the 21st cCentury. In E.-P. Lim *et al*. Eds.: ICADL 2002, *Lecture Notes in Computer Science, 2555*, pp. 1-13.

Brin, S., Page, L. (1998). The anatomy of a large-scale hypertextual web search engine. *Computer Networks and ISDN Systems*, *30*, 107-117.

Bronfenbrenner, U. (1979). *The ecology of human development*. Cambridge: Harvard University Press.

Chi, E.H., Pirolli, P., Chen, K., Pitkow, J. (2001). Using information scent to model user information needs and actions on the Web. In *Proceedings of ACM CHI 2001 Conference on Human Factors in Computing Systems*, pp. 490—497. Seattle, WA: ACM Press.

Coleman, A. (2006). Commons-based digital libraries. (working paper). Retrieved October 30, 2006, from http://dlist.sir.arizona.edu/1187/01/AscSigSi06.pdf.

Computer Science and Telecommunications Board. (1998). Design and evaluation. *D-Lib Magazine*. Retrieved April 10, 2003, from http://www.dlib.org/dlib/july98/nrc/07nrc.html.

Cooper, R.G. (1979). The dimensions of industrial new product success and failure. *Journal of Marketing*, *43*, 93-103.

Cooper, R.G. (1983). The impact of new product strategies. *Industrial Marketing Management*, *12*, 243-256.

Dalrymple, P.W., Zweizig, D.L. (1992). Users' experience of information retrieval systems: an exploration of relationship between search experience and affective measures. *Library and Information Science Research*, *14*, 167-181.

Davis, F.D. (1993). User acceptance of information technology: system characteristics, user perceptions, and behavioral impacts. *International Journal of Man-Machine Studies*, *38*, 475-487.

De Mey, M. (1977). The cognitive view point: its development and its scope. In: de Mey, M., Pinxten, R, Poriau, M., Vandamme, F. Eds CC77: *International Workshop on the Cognitive ViewPoint*, March 24-26, 1977: Ghent, Belgium. Ghent, Belgium: University of Ghent: xvi-xxxi.

Ellis, D. (1989). A behavioral approach to information retrieval system design. *Journal of Documentation, 45*, 171-212.

Engeström, Y., Miettinen, R., Punamaki, R. (1999). *Perspectives on activity theory*. Cambridge, Ma.: Cambridge University Press.

Ernst, H. (2002). Success factors of new product development: a review of the empirical literature. *International Journal of Management Review*, *4*, 1-40.

Eschenfelder, K. (2006). What is an authorized use? The social construction of access and use rights restrictions in licensed scholarly digital resources protected by technological protection measures. (working paper). Retrieved October 30, 2006 from http://dlist.sir.arizona.edu/1472/02/SymposiumfinalEsch.pdf.

Fox, E.A., Akscyn, R.M., Furuta, R.K., Leggett, J.J. (1995). Digital Libraries – introduction, *Communications of the ACM*, *38*, 23-28.

Fox, E.A., Urs, S.R. (2002). Digital libraries. *Annual Review of Information Science and Technology*, *36*, 503-589.

Gay, G., & Hembrooke, H.. (2004). *Activity based design: an ecological approach to design smart tools and usable systems*. Boston: MIT Press.

Garfinkel, H. (1967). Studies in Ethnomethodology. New Jersey: Prentice Hall.

Hsieh-Yee, I. (2001). Research on web search behavior. *Library and Information Science Research*, *2*, 167-185.

Jacob, E.K., Shaw, D. (1998). Sociocognitive perspectives on representation. *Annual Review of Information Science and Technology*, *33*, 131-185.

Kahle, B. (1997). Preserving the Internet. *Scientific American*, 276, 82-83.

Kelly, G.A. (1963). *A theory of personality: The psychology of personal constructs*. New York: Norton.

Kohli, A.K., Jaworski, B.J. (1990). Market orientation: the construct, research propositions, and managerial implications. *Journal of Marketing*, *13*, 137-151.

Kuhlthau, C. (1991). Inside the search process: information seeking from the user's perspective. *Journal of the American Society for Information Science*, *42*, 361-371.

Levy, D. (1995). Cataloging in the digital order. In F. M. Shipman, R. Furuta, D. M. Levy Eds., *Proceedings of Digital Libraries '95*. Austin, Texas, ACM Press.

Lucier, R.E. (1995). Building a digital library for the health sciences: information space complementing information space. *Bulletin of the Medical Library Association*, *83*, 346-350.

Maly, K., Nelson, M.L., Zubair, M. (1999). Smart objects, dumb archives: a user-centric, layered digital library framework. *D-Lib Magasine*, *5*. Retrieved April 10, 2003 from http://www.dlib.org/dlib/march99/maly/03maly.html.

Marchionini, G. (1992). Interfaces for end-user information seeking. *Journal of the American Society for Information Science*, *43*, 156-163.

Morse, E.L. (2002). Evaluation methodologies for information management systems. *D-Lib Magazine, 8*. Retrieved April 10, 2003 from http://www.dlib.org/dlib/september02/morse/09morse.html.

Nahl, D. (1996). Affective monitoring of internet learners: perceived self-efficacy and success. In S. Hardin Ed., Information, Chaos, and Control. *Proceedings of the American Society for Information Science*, *33*.

Nardi, B.A. (1996). Activity theory and human-computer interaction. In B.A. Nardi (Ed.), *Context and consciousness: Activity Theory and human-computer interaction* pp.7-16, Cambridge, Ma: The MIT Press.

National Science Foundation. (2002). Digital libraries. Retrieval May 20, 2006 from http://www.nsf.gov/news/news_summ.jsp?cntn_id=103048.

National Science Foundation. (2004). Digital Library for Earth System Education (DLESE) Project office. Retrieval May 20, 2006 from http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=12804.

Nielsen, J. (2000). Why you only need to test with 5 users. Accessed May 20, 2006 from http://www.useit.com/alertbox/20000319.html.

Pan, B. (2003). *Capturing users' behavior in the National Science Digital Library NSDL*. Unpublished Report. Cornell University: Human-Computer Interaction Research Group.

Pirolli, P., & Card, S.K. (1999). Information foraging. *Psychological Review*, *106*, 643-675.

Ratchford, B.T., Talukdar, D., & Lee, M. S. (2001). A model of consumer choice of the Internet as an information source. *International Journal of Electronic Commerce*. *53*, 7-21.

Saracevic, T. (1991). Individual differences in organizing, searching, and retrieving information. In J.M Griffiiths Ed., *Proceedings of the American Society for Information Science ASIS*, *58*, 82-86. 54th Annual Meeting. October 27-31, Washington, DC. Medford, NJ:Learned Information Inc.

Thong, J.Y.L., Hong, W., & Tam, K. (2002). Understanding user acceptance of digital libraries: what are the roles of interface characteristics, organizational context, and individual differences?. *International Journal of Human-Computer Studies*, *57*, 215-242.

Tuominen, K., Talja, S., & Savolainen, R. (2003). Multiperspective digital libraries: the implications of constructionism for the development of digital libraries, *Journal of the American Society for Information Science and Technology*, *54*, 561-569.

Weedman, J. (1998). The structure of incentive: Design and client roles in application-oriented research. *Science, Technology, and Human Values*, 23 (3), 315-345.

Wilson, T.D. (1981). On user studies and information needs. *Journal of Documentation*, 367, 3-15.

Wilson, T.D. (1997). Information behavior: an interdisciplinary perspective. *Information Processing and Management*, *33*, 551-562.