Interim Report on
Interactive Learning with a Digital Library in Computer Science

October, 1996

1. Details

Award Number: NSF CDA 9312611
Amount of Award: $449,088
Period of Award: 8/15/93 - 1/31/97
Project Director: Edward A. Fox
Co-PIs: JAN Lee, Clifford Shaffer, H. Rex Hartson, N. Dwight Barnette
Title: Interactive Learning with a Digital Library in Computer Science

2. Summary of Publications

Project Overviews: FOXE94e, FOXE95c, FOXE96d, FOXE96f
Digital Library - General: CHEN96, DOUG95, FOXE93b, FOXE93d, FOXE93e, FOXE94d, FOXE95a, FOXE96b
Digital Library - Architecture: FOXE94b, FOXE95f, FOXE96c, GLAD94a, GLAD94b
Digital Library - Capture, Conversion: DALA93
Digital Library - CS Technical Reports: FOXE95b, FREN95, MALY94a, MALY94b
Digital Library - Education: FOXE96a, FOXE96d, FOXE95e, FOXE96e, LAUG96
Digital Library - Interface: NOWE94, NOWE96, WAKE95a
Digital Library - System: FOXE93c, FOXE94c, HEAT95
Interactive Applications: WAKE95b, WAKE95c
Interactive Learning: SHAF96a, SHAF96b, TINO96, YANG95
Networking: ABRA95a, ABRA95b, FOXE94a, WILL96

3. Summary of Results

In 1991 Virginia Tech began working with ACM through support from NSF on a "User-Centered Database from the Computer Science Literature" [HEAT95]. In 1993, Virginia Tech expanded its work on digital libraries to launch the NSF funded project "Interactive Learning with a Digital Library" in Computer Science, partnering with Norfolk State University, which has developed extensive sets of laboratory manuals. Over 25 courses are available through WWW, leading to over 1.8M accesses since 1995.

Now there are several gigabytes of ACM publications available. A server to handle authentication and other tasks has been installed at ACM Headquarters in NYC. Ongoing collaboration between ACM and Virginia Tech is being expanded to include IBM Research and their digital library systems.

Several courses have all the on-line materials required for self-study available, and new programs are under development for distance learning and continuing education. In the Multimedia course, there was a dramatic increase in bandwidth required for the 1996 offerings as compared to the 1995 ones, because of more images, digital audio, and digital video. Due to the development by Prof. Lee (editor of *Annals of the History of Computing*) of one of the largest repositories on computer history, with a unique image collection of the founders and early systems in our field, there is extensive additional traffic from throughout the nation. In 1996, with the help of NSF-funded digital video capture and editing facilties, audio annotations, digital video movies, and animations to show interactive applications have been added. One of the courses developed under this effort, and extended through support from SUCCEED, is CS1604, an introduction to networked information. A self-study version of this course will be finalized later in 1996, and is expected to be widely used throughout the Southeast and beyond by those interested in a freshman or beginner-level orientation to Internet, digital libraries, collaboration technologies, etc. This version has numerous audio and movie files to help learners, an automated real-time feedback facility (using our SGML-based QUIZIT tool [TINO96]), and a variety of illustrations and demonstrations.

Starting with InfoRetrieval and continuing with the Multimedia and NetInfo courses, we have adapted Keller's Personalized System of Instruction [KELL68] to our networked environment. Students proceed at their own pace,

study on their own, get help through asynchronous communication with peers and instructors, and in general have much greater flexibility in learning. Many students prefer this type of course, and in the case of NetInfo we simply could not accomodate the demand any other way, in this time of scarce resources. However, students have requested that we add interim deadlines, since they tend to procrastinate and require help with time management.

Our evaluation involves typical traditional methods, e.g., pre- and post-tests, surveys, and focus groups. We performed usability studies of tools we developed or applied, and used formative evaluation methods to refine both our tools and courseware. Yet, our project still requires additional approaches to evaluation.

The investigators in our project are instructors who changed their allocation of time, behavior, pedagogy, course materials, and tools. To understand the effects of these changes, ethnographic practices are of great value - especially regarding use of asynchronous communication (i.e., online debates) [LAUG96].

Another shift in our evaluation has been to rely on network monitoring, logging, and analysis. Here we draw upon special tools for this purpose [ABRA95a]. Part of this work has helped improve our quality of service through caching [ABRA95b]. The rest has helped us understand what students really do, what course materials are accessed, how use of multimedia effects network traffic, and how both remote and local accesses increase over time. Figure 1 shows recorded accesses of the EI server from January 1995 through May 1996. Robot accesses and indexing runs have been removed from the data, except at the time of the first peak shown. There has been a gradual increase in both remote and total access counts, if we ignore the valleys occuring during mid-semester, summer, and end-of-year breaks. We believe that the remote accesses reflect growing interest in and use of our repository, for each course (see Figure 2).

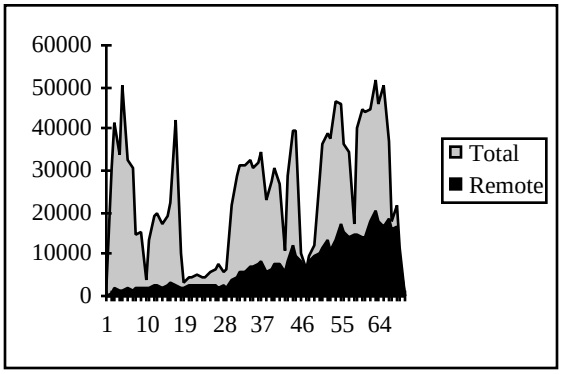

Figure 1. Weekly Accesses 1/95 - 6/96

In summary, we have developed tools, expanded our digital library systems and content, and built almost 5000 “pages” of WWW-accessible courseware, increasing the interactivity and quality of learning about computer science. Evaluation has shown that learning practices have changed, most students are happy with the emerging infrastructure and pedagogy, and there is growth in both local and remote access to our server.

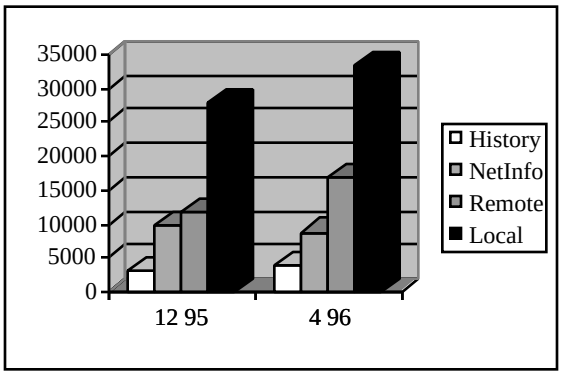

Figure 2. Accesses for Last Week of Semester

Objectives/Accomplishments: Key concepts of our 1993-1996 NSF-funded Education Infrastructure project [FOXE95c] are to improve CS education by increasing interactivity and use of a digital library. The main objectives/accomplishments were to:

- expand the content and software (especially interfaces [NOWE84, NOWE96, WAKE95a]) initially developed with NSF support of our "Envision" digital library project, "A User-Centered Database from the Computer Science Literature" [HEAT95],
- develop/apply algorithm visualization tools that are easy for instructors to use in supplementing courses, and feasible for students to work with as an aid to program development and debugging [YANG95, SHAF96a, SHAF96b],
- incorporate use of specialized digital library systems like Netlib into related courses,
- add new courses related to human-computer interaction, multimedia, and a freshman level introduction to Networked Information,
- significantly change courses like "Computer Professionalism," to make use of interactivity (e.g., asynchronous online debates) and digital library support (e.g., adding to a large History collection), and
- apply the key concepts to improve other courses.

Resulting changes have far exceeded our expectations.

4. Contributions to Development of Human Resources

Our work has helped train hundreds of students, has aided the work of instructors interested in teaching courses for which we have developed useful materials, has developed tools (e.g., SWAN, QUIZIT) that can increase the interactivity of learning about computer science, and has helped with the construction of digital library systems and a content collection in CS (with ACM publications as well as technical reports).

5. Deliverables

One result of our effort is the prototype Envision system. Its interface, if ported to Java, and connected to Z39.50, could be a very convenient means for accessing a variety of bibliographic collections, as well as richer digital libraries. A second result is the content converted from ACM. The most convenient portion is several hundred articles from CACM available now for those with permission using the Dienst system. A third result is the software created in increase interactivity of learning: SWAN and QUIZIT. Finally, there are about 5000 WWW pages of CS courseware. Table 1 shows the amount of online material developed in four courses; seven others also have 175 or more HTML pages.

Course/Files	*HTML*	*GIF*
NetInfo	175	300
CompProf	600	350
Multimedia	525	250
InfoRetrieval	350	125

Table 1. Counts of Active Files for Selected Courses

Usage for those materials has grown steadily in the last 18 months. Remote users now make up a significant portion of the bases of those requesting pages, adding to the hundreds of students served locally.

6. Connections and Extensions

Ongoing collaboration with Norfolk State University (NSU) has led to an increase in the use of laboratories to aid learning of CS students at Virginia Tech, and adaptation of many of the Virginia Tech materials and tools for use at NSU. Another systematic extension has been facilitated by additional funding from NSF through Southeastern University and College Coalition for Engineering EDucation (SUCCEED). The SUCCEED Coalition Grant "Using Computers and Networked Information: Distance Learning with Networked Multimedia" is expanding through the use of digital video/audio tutorials, an alternative VRML (Virtual Reality Markup Language) interface, multiple graphic pathways, an interactive collaboration medium for synchronous communication, and an online interactive real time testing component. Outreach work with a number of universities in the region is underway to help them apply this course to help them deal with increased interest in this field, and to more closely approach full "Information Literacy."

7. References

[ABRA95a] M. Abrams, S. Williams, G. Abdulla, S. Patel, R. Ribler and E. Fox. Multimedia Traffic Analysis Using Chitra95. In Proc. 3rd Int. Multimedia Conf. and Exhibition, Multimedia '95, San Francisco, Nov. 5-9, 1995, 267-276.

[ABRA95b] M. Abrams, C. R. Standridge, G. Abdulla, S. Williams and E. A. Fox. Caching Proxies: Limitations and Potentials, in Proc. 4th International World-Wide Web Conference, Boston, Dec. 1995. URL: http://ei.cs.vt.edu/~succeed/WWW4/WWW4.html

[CHEN96] Su-Shing Chen and E. Fox. Guest Editors' Intro. to Special Issue on Digital Libraries, in press for Journal of Visual Communication and Image Representation, 1996.

[DALA93] K. Dalal and E. Fox. Document Translation: Dissertations and Technical Reports, TR-93-31, VPI&SU Computer Science Dept., Sep. 21, 1993, Blacksburg, VA.

[DOUG95] W.C. Dougherty and E.A. Fox. TULIP at Virginia Tech. Library Hi Tech, 13(4):54-60, 1995.

[FOXE93b] E. Fox and L. Lunin. Introduction and Overview to Perspectives on Digital Libraries. Journal of the American Society for Information Science (JASIS), Sept. 1993, 44(8): 441-443.

[FOXE93c] E. Fox, D. Hix, L. Nowell, D. Brueni, W. Wake, L. Heath, and D. Rao. Users, User Interfaces, and Objects: Envision, a Digital Library. JASIS, Sept. 1993, 44(8): 480-491.

[FOXE93d] E. Fox. Digital Libraries ("hot topics"), IEEE Computer, Nov.1993, 26(11):79-81.

[FOXE93e] E. Fox, ed. Sourcebook on Digital Libraries: Report for the National Science Foundation, TR-93-35, VPI&SU Computer Science Dept., Dec. 1993, Blacksburg, VA. Available by FTP from directory pub/DigitalLibrary on fox.cs.vt.edu

[FOXE94a] E. Fox and G. Abdulla. Digital Video Delivery for a Digital Library in Computer Science. High-Speed Networking and Multimedia Computing Workshop, IS&T/SPIE Symposium on Electronic Imaging Science and Technology, Feb. 6-10, 1994, San Jose, CA, 7 pages.

[FOXE94b] E. Fox. Seamless Multimedia Integration for Digital Libraries. Invited position paper for Dagstuhl Seminar on Fundamentals and Perspectives of Multimedia Systems, International Conf. and Research Center for Computer Science, Dagstuhl Castle, Germany, July 4-8, 1994, 118-123.

[FOXE94c] E. Fox. A digital library connecting Envision, KMS, and Mosaic with interfaces, communications, and data interchange. Invited presentation for 1994 Workshop on Digital Libraries: Current Issues, sponsored by: Rutgers and Purdue Universities, AT&T and Bellcore, at Rutgers Univ., Newark, NJ, May 19-20, 1994. Abstract in SIGOIS Bulletin, Aug. 1994, 15(1):6.

[FOXE94d] E. Fox. How to make intelligent digital libraries. In Methodologies for Intelligent Systems, Proceedings of the 8th International Symposium, ISMIS'94, Charlotte, NC, Oct. 1994. Lecture Notes in Artificial Intelligence 869, Springer-Verlag, Berlin, 27-38.

[FOXE94e] E. Fox and D. Barnette. Improving Education through a Computer Science Digital Library with Three Types of WWW Servers. In Proc. Second International WWW '94: Mosaic and the Web, WWW'94, Chicago, IL, Oct. 17-20, 1994.

[FOXE95a] E. Fox, R. Akscyn, R. Furuta, and J. Leggett. Guest Editors' Introduction to Digital Libraries. Commun. ACM, Apr. 1995, 38(4):22-28. Also co-authored 3 other pieces in that issue, about the Envision system and CS reports.

[FOXE95b] E. Fox. World-Wide Web and Computer Science Reports. Commun. of the ACM, Apr. 1995, 38(4):43-44.

[FOXE95c] E. Fox, N. Barnette, C. Shaffer, L. Heath, W. Wake, L. Nowell, J. Lee, D. Hix, and H. Hartson. Progress in Interactive Learning with a Digital Library in Computer Science. Invited paper for Proc. ED-MEDIA 95, World Conference on Educational Multimedia and Hypermedia, Graz, Austria, June 17-21, 1995, pp. 7-12.

[FOXE95e] E. Fox and L. Kieffer. Multimedia Curricula, Courses and Knowledge Modules, ACM Computing Surveys, Dec. 1995, 27(4): 549-551.

[FOXE95f] E. Fox. Hypermedia Support for a Digital Library in CS. SIGLINK Newsletter, Sept. 1995, 4(2), Special Issue on Digital Libraries.

[FOXE96a] E. Fox. Digital Library Support for Education - A Case Study of Advanced Networked Information Systems, Invited presentation for Dagstuhl Workshop on Networked Information Systems - Discovery, Retrieval, Dissemination, Feb. 26 - March 1, 1996, Dagstuhl, Germany.

[FOXE96c] E. Fox. Virginia Tech Department of Computer Science Information Access Laboratory. ACM SIGIR Forum, Lab Report Special Section, 30(1), Spring 1996.

[FOXE96d] E. Fox. Digital Libraries, WWW, and Educational Technology: Lessons Learned. Invited paper for Proc. ED-MEDIA 96, World Conference on Educational Multimedia and Hypermedia, Boston, MA, June 17-22, 1996, 246-251. See also http://ei.cs.vt.edu/~fox/EDMEDIA96/

[FOXE96e] E. Fox, J. Eaton, G. McMillan, N. Kipp, L. Weiss, E. Arce, S. Guyer. National Digital Library of Theses and Dissertations: A Scalable and Sustainable Approach to Unlock University Resources. D-Lib Magazine, ISSN 1082-9873, Sep. 1996.

[FOXE96f] E. Fox. Interactive Learning with a Digital Library in Computer Science. Invited paper for Proc. Frontiers in Education - FIE'96, Salt Lake City, Utah, Nov. 6-9, 1996, to be given.

[FREN95] J. French, E. Fox, K. Maly, and A. Selman. Wide Area Technical Report Service --- technical reports online. Commun. of the ACM, Apr. 1995, 38(4):45.

[GLAD94a] H. Gladney, Z. Ahmed, R. Ashany, N. Belkin, E. Fox and M. Zemankova. Digital Library: Gross Structure and Requirements (Report from a Workshop). IBM Research Report RJ9840, IBM Almaden Research Center, May, 1994. Virginia Tech Dept. of Computer Science Technical Report 94-25, June, 1994.

[GLAD94b] H. Gladney, E. Fox, Z. Ahmed, R. Ashany, N. Belkin, and M. Zemankova. Digital Library: Gross Structure and Requirements: Report from a March 1994 Workshop. Digital Libraries '94, June 19-21, 1994, College Station, TX, ed. J. Schnase, J. Leggett, R. Furuta, T. Metcalfe, 101-107.

[HEAT95] L. Heath, D. Hix, L. Nowell, W. Wake, G. Averboch, and E. Fox. Envision: A User-Centered Database from the Computer Science Literature. Commun. of the ACM, Apr. 1995, 38(4):52-53.

[LAUG96] S. Laughton. An ethnographic study of Internet-based applications in education. Ph.D. Dissertation, Dept. of Computer Science, Virginia Tech, Blacksburg, VA, May 1996.

[MALY94a] K. Maly, J. French, A. Selman and E. Fox. Wide Area Technical Report Service, TR_94_13, Old Dominion Univ. Dept. of Computer Science, June 1994.

[MALY94b] K. Maly, J. French, A. Selman and E. Fox. The Wide Area Technical Report Service. In Proc. Second International WWW '94: Mosaic and the Web, WWW'94, Chicago, IL, Oct. 17-20, 1994, 523-533.

[NOWE94] L. Nowell, E. Fox, L. Heath, D. Hix, W. Wake and E. Labow. Seeing Things Your Way: Information Visualization for a User-Centered Database of Computer Science Literature, TR-94-06, VPI&SU Computer Science Dept., Jan. 1994, Blacksburg, VA.

[NOWE96] L. Nowell, D. Hix, R. France, L. Heath, and E. Fox. Visualizing Search Results: Some Alternatives to Query-Document Similarity, in Proc. SIGIR'96, Zurich, Switzerland, Aug. 18-22, 1996.

[SHAF96a] Shaffer, C.A., Heath, L.S., and Yang, J., Using the Swan Data Structure Visualization System for Computer Science Education, *Proc. SIGSCE '96*, Philadelphia PA, February 1996.

[SHAF96b] C. Shaffer, L. Heath, J. Nielsen, and J. Yang. SWAN: A Student-Controllable Data Structure Visualization System. In *Proc. ED-MEDIA 96, World Conference on Educational Multimedia and Hypermedia*, Boston, June 17-22, 1996, 632-637.

[TINO96] Tinoco, L., *et al.* QUIZIT: An Interactive Quiz System for WWW-based Instruction. http://pixel.cs.vt.edu/~ltinoco/quizit/QUIZIT.PS (Postscript format) 1996.

[WAKE95a] W. Wake and E. Fox. SortTables: A Browser for a Digital Library. In Proc. 4th Int. Conf. Information and Knowledge Management, CIKM '95, Baltimore, MD, Nov. 28 - Dec. 2, 1995, 175-181.

[WAKE95b] Wake, W., Wake, B. D., and Fox, E., Improving Responsiveness in Interactive Applications Using Queues. *Proc. Pattern Languages of Program Design 2*, PLOP '95.

[WAKE95c] Wake, W., Wake, B. D., and Fox E., Improving Responsiveness in Interactive Applications Using Queues. In Vlissides, Coplien, and Kerth, Eds., *Pattern Languages of Program Design 2*, Addison-Wesley (in press). Previously published in Proc. PLOP '95.

[WILL96] S. Williams, M. Abrams, C. Standridge, G. Abdulla, E. Fox. Removal Policies in Network Caches for World-Wide Web Documents, in Proc. SIGCOMM '96, Palo Alto, CA, Aug. 28-30, 1996.

[YANG95] Yang, J., Shaffer, C.A., and Heath, L.S., SWAN -- A Data Structure Visualization System, *Proceedings of Graph Drawing '95*, Passau Germany, pp. 520-523, September 1995.