What's DUE

A National Digital Library for Science, Mathematics, Engineering, and Technology Education

NORMAN L. FORTENBERRY,[1] JAMES J. POWLIK[2]

[1] *Division of Undergraduate Education, National Science Foundation, 4201 Wilson Boulevard, Room 835, Arlington, Virginia 22230*

[2] *Raggedtooth Productions, 9919-A Gable Ridge Terrace, Rockville, Maryland 20850*

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In a previous column on information technology (*CAE*, Vol. 6, No. 3), we indicated interest in the application of digital libraries to undergraduate education. In this column, we will expand on that interest, indicate efforts that the National Science Foundation has taken based on that interest, and lay out a vision of future possibilities.

INTRODUCTION

Faculty, teachers, software developers, publishers, and a host of others are contributing to the development of rich and engaging new environments for active, inquiry-driven learning. These advances draw much of their vigor from the technological revolution that has put enormous computational power on desktops; that has created networks that bridge distance, discipline, institution, and even culture; and that has created a new generation of powerful, flexible, and inexpensive experimental equipment. The recently released Interim Report of the President's Information Technology Advisory Committee [1] offers a compelling vision of what is possible:

> Any individual can participate in on-line education programs regardless of geographic location, age, physical limitation, or personal schedule. Everyone can access repositories of educational materials, easily recalling past lessons, updating skills, or selecting from among different teaching methods in order to discover the most effective style for that individual. Educational programs can be customized to each individual's needs, so that our information revolution reaches everyone and no one gets left behind.

The National Science Foundation (NSF) is contributing to the achievement of this vision; together with other agencies, the NSF is supporting fundamental work in digital libraries through the Digital Libraries Initiatives [2]. To selectively extend digital library research and test-bed activities in promising areas, an expanded set of agencies is cooperating on Phase 2 of the Digital Libraries Initiative (DLI-2) [3]. One aspect of DLI-2 is investigation of the applicability of digital library technology to science, mathematics, engineering, and technology (SMET) education. A national digital library could be a natural next step, building on foundational

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Correspondence to N. L. Fortenberry.

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work in computer science, networks, and digital libraries to leverage and disseminate advances in the content and practice of SMET education (SMETE).

For convenience, we will refer to the concept of such a resource as a National SMETE Digital Library (NSDL). Capitalizing on recent developments in digital libraries, an NSDL could provide

- a forum for the review, recognition, registry, and archive of quality educational resources with embedded indications of targeted audiences and suggested modes of usage;
- a resource for research on teaching and learning as well as electronic dissemination of information about high-quality educational materials, pedagogical practices, and implementation strategies;
- a platform for traditional, continuing, and distance education using validated materials and methods; and
- a domain where research and education are integrated via access to data sets and simulations as well as synchronous and asynchronous communities of learners at all levels.

A fully implemented NSDL could attain immediate use at the precollege, undergraduate, and graduate levels, as well as provide a mechanism for continuing education. In many respects, NSDL could move well beyond the image of a library. In addition to providing timely and wide access to up-to-date, high-quality resources for SMETE, an NSDL could exploit the connectivity provided by the Internet and the potential of interactive technologies to create a rich, asynchronous workplace—a seminar room, a reading room, and laboratory for sharing and building knowledge. Consequently, an NSDL could provide a framework for facilitating the work of people in different settings through a diverse and powerful set of resources.

DEVELOPMENT FRAMEWORK

It is assumed that the World Wide Web would be the operating platform for an NSDL. However, creation of an NSDL faces the challenge of overcoming the Web's weaknesses without losing its strengths: providing selectivity without excessive screening, providing assured links without inhibiting the provision of the most recent information, and serving as a stable platform without being overly restrictive in its operating rules. An NSDL should provide an open, robust, and reliable framework for significant advances in SMETE at the same time as it serves as a vehicle for dissemination of the best SMETE content and practice.

The success of the World Wide Web is in large part a consequence of the philosophy on which it is based. There are enough standards to enable it to work, but because its architecture is open, it has been able to evolve. An NSDL would add another layer of standards while maintaining the open architecture of the Web. The new standards would include metadata and universal object identifiers that would help users find appropriate and high-quality resources. They would also provide a measure of reliability and stability that is missing now from the Web. New interoperability and reusability standards would facilitate connections between disciplines and new resources that build on previous ones.

RECENT ACTIVITIES SUPPORTED BY NSF

Since 1993, the NSF Division of Undergraduate Education (DUE) has supported projects that could inform progress toward an NSDL. Included among DUE-supported projects are those developing hypermedia curricular materials to take advantage of the World Wide Web in such areas as genetics [4], geography [5], and radio astronomy [6]. DUE has also supported the development of repositories and registries for curricular materials in physics [7], computer science [8], mathematics [9], and the social sciences [10]. Within the past year, DUE has contributed support for additional sites in manufacturing [11], biology [12], an additional site in computer science [13], and an interdisciplinary effort in physics and computer science [14]. Finally, DUE has supported projects that explore the virtual community aspects of shared curriculum development (e.g., another project in geography [15]) and virtual work environments (e.g., a project in chemistry [16]). Under the DLI-2 initiative, DUE has supported three additional awards that seek to explore realization of digital libraries devoted to education [17–19].

In April 1996, DUE sponsored a workshop on the educational uses of technology. The report of that workshop [20] documents the participants' recognition of the potential of Web-based systems, as well as the importance of focusing on the needs of end users with highly variable backgrounds. In response to a July 1997 National Research Council (NRC) workshop [21], DUE began a more focused exploration of the feasibility of establishing a virtual facility—an NSDL. The NRC report suggests that the notion merited serious consideration, but urged obtaining greater input from potential users.

Part of the response to the report was DUE participation in the DLI-2 initiative. In fiscal year 1998, DUE committed $500,000 toward the support of a portfolio of projects that will explore specific aspects of the practical implementation of an electronic library—for example, organizational schemes, acquisition and review processes, robust linkages to sites of various content domains, metatag strategies, investigations of suitability of content in various disciplines or domains of interest, and assessment of impact on learning and teaching strategies. These projects, working together with selected projects supported by DLI-2 and by core DUE programs, will serve as test beds for the distributed architecture discussed below and will inform our future efforts.

REPORT ON THE DISCUSSIONS AT AN AUGUST 1998 WORKSHOP

Another response to the NRC report was an August 1998 DUE-sponsored workshop held to gather the perspectives of potential users, content developers, digital library specialists, and educational researchers on such issues as desired levels and modes of user support, developer support, scope of content, quality control, maintenance and interoperability, and potential impacts on teaching and learning [22]. The forthcoming report will provide conclusions reflecting the consensus arrived at during the workshop. The comments below are based on our interpretation of the issues discussed and their potential implications for developing and implementing an NSDL.

Management

First and foremost, an NSDL would be a virtual facility providing resources and services (principally as a test bed for teaching, learning, collaboration, and research within SMET disciplines and educational research) to its client communities. It might be helpful to think of a telescope or beam source that provides access to an external community of users. Therefore, some analog to a prime contractor for a physical facility would be required to oversee the "construction" of an NSDL. A managing body is envisioned that would be responsible for overall coordination, including setting the minimal standards necessary to ensure the interoperability of the library's components and their reliability. The managing body might also periodically specify hardware/software packages of target functionality for both developers and users. Users purchasing such packages would know that they would support most of the library's resources and developers would know that staying within the confines of such packages would result in a larger potential group of users.

Architecture

Discussions at the workshop suggested that it would be desirable for an NSDL to have a distributed physical architecture while exhibiting both federated and confederated structures. NSDL Central would be the entity responsible for NSDL operations. NSDL Central may or may not exhibit overlap with the managing body for NSDL's construction. Beyond NSDL Central would be core partners who, as part of a solid federation, would adhere to strong guidelines and operating standards. More loosely connected in an extended confederation (think of a political alliance) would be NSDL affiliates who would adhere to a less stringent set of guidelines and standards in exchange for gaining access to NSDL materials and services and making their own materials and services available to the NSDL communities.

Perhaps 100 "collections" would contain the library's holdings and be managed by the core partners—for example, educational institutions, professional societies, publishers, and government agencies (NSF itself might maintain a collection). An NSDL would grow by adding new collections and by expanding its existing collections. All the collections would be required to adhere to minimal standards for interoperability and to ensure reliability and robustness, but different collections might have different acquisition standards. One site might include only material carefully selected after extensive refereeing and testing, while another site (perhaps that of an NSDL affiliate) might contain gray material—sacrificing consistent quality in favor of currency and the immediacy of discussing works in progress.

Content

An NSDL could make a significant contribution to both the quality and reach of SMETE simply by increasing access to the same materials that are currently found in only a few places now. The real power of such a library, however, derives from the difference between electronic and paper resources. The library's holdings would include rich multimedia and interactive materials, large and real-time data sets, simulations, microcosms, and—most important—tools.

Services

It was noted at the workshop that provision of services would be the key to achieving true utility to NSDL

user communities. Some services would serve users directly, some would serve collections, and others would serve other services. The list of services might be expected to include, among others,

- Portals or front ends providing access to the library's collections and optimized for different users and different purposes. Although all portals would provide access to the same collections, they could be designed to meet the particular needs of their own users quickly and efficiently.
- Multidimensional search mechanisms which themselves employ several single-dimensional search mechanisms. Users would be able to request a list of hits selected and prioritized on the basis of a combination of content, metadata, citations [23], and reviews by third parties.
- Help services for users including Web-based help and, perhaps, toll-free telephone lines.
- Facilitated colloquia on topics of interest to various user communities.
- User-initiated chat rooms to explore the utility of various content, share ideas, and build virtual self-supporting communities of users.
- Cataloging services for content developers and collections to provide metadata.
- Reviewing mechanisms using universal identifiers will enable the linking of reviews by third parties to library resources. For example, faculty planning a course will have access not only to classroom and laboratory resources, but also to comments by discipline experts and by faculty, students, and other users.
- Testing services to help ensure the reliability and stability of resources—for example, testing Java applets under various operating systems and browsers and by verifying links.
- Libraries of inexpensive generic software or limited versions of commercial software to provide a lower cost alternative for students and faculty at institutions unable to afford site licenses for expensive, full-featured commercial software.
- Virtual reading rooms to serve as mechanisms for distributed, collaborative work using shared resources and tools.
- Networks of load-balancing, high-demand, fault-tolerant servers able to handle millions of hits from students. Users should not know whether their requests are being answered by the original site or by a mirror site constructed on the fly in response to high demand.

FUTURE DEVELOPMENTS

Over the next several years, DUE plans to support projects that will help to answer key questions regarding the application of digital library technology to SMETE. As previously indicated, these questions relate to organizational schemes, acquisition and review processes, robust linkages to sites of various content domains, metatag strategies, investigations of suitability of content in various disciplines or domains of interest, and assessment of impact on learning and teaching strategies.

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BIOGRAPHIES

Norman L. Fortenberry is director of the Division of Undergraduate Education at the National Science Foundation. He is a clinical associate professor of mechanical engineering at Rensselaer Polytechnic Institute. Previously, Dr. Fortenberry served as executive director of the National Consortium for Graduate Degrees for Minorities in Engineering and Science, Inc. During earlier NSF service, Dr. Fortenberry served as a program director for engineering and as a staff associate within the Division of Undergraduate Education. Before joining the NSF in 1992, Dr. Fortenberry was a faculty member at Florida A&M University/Florida State University College of Engineering, where he taught and conducted research in the area of design theory and methodology.

James J. Powlik is an information dissemination specialist and was a consultant to the National Science Foundation from 1995 to 1997. As director of Raggedtooth Productions, Dr. Powlik has advised on technical content, education efficacy, program design, and public outreach for clients including NSF, NASA, the U.S. Department of Commerce, public attractions, nonprofit organizations, and programs for students in kindergarten through graduate school. As a biologist and oceanographer, he has authored research papers, texts, and novels on vertebrate morphology, aquatic ecology, and ocean science.