The National Science, Technology, Engineering, and Mathematics Education Digital Library (NSDL) Program: Progress and Potential

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Abstract

This paper explains the background of the NSDL program and details the program structure along with a short description of progress to date with pointers to complete project descriptions. In addition it provides technical information about the NSDL metadata framework and outlines new program components introduced for fiscal year (FY) 2004. Finally, implications for engineering education are discussed.

Introduction and background

The National Science Foundation's (NSF) National Science, Technology, Engineering, and Mathematics Education Digital Library (NSDL) program seeks to create, develop, and sustain a national digital library supporting science, technology, engineering, and mathematics (STEM) education at all levels. By supporting broad access to rich, reliable, and authoritative sets of interactive learning and teaching materials and associated services in a digital environment, the National Science Digital Library is expected to catalyze continual improvements in the quality of STEM education for all students, and also serve as a resource for lifelong learning.

The program traces its roots to concept papers developed within the NSF Division of Undergraduate Education (DUE) in late 1995. Earlier that year NSF had launched the interagency Digital Libraries Research Initiative (DLI), and DUE staff saw an opportunity to apply these emerging research findings to the creation of a national digital resource for STEM education. While the initial motivation focused on enabling systematic access to NSF-supported educational materials at the undergraduate level, the scope quickly expanded to embrace a larger set of learning resources addressing all educational levels. Over the period of several years a series of workshops explored this idea further with findings documented in various reports and monographs [1-9]. These efforts characterized the digital library as a learning environments and resources network for science, technology, engineering, and mathematics education. The resulting virtual facility should:

- center on the learner, either individually or in collaborative settings;
- enable dynamic use of a rich array of digital learning materials; and
- promote reliable anytime, anywhere access to quality collections and services.

For a further discussion of the vision and prospects for the growth of NSDL, please see http://www.dlib.org/dlib/march01/zia/03zia.html [10].

In FY 1998 and FY 1999 a precursor to the NSDL program was conducted through the Special Emphasis: Planning Testbeds and Applications for Undergraduate Education under the auspices of the multi-agency DLI-2 program (http://www.dli2.nsf.gov). Information about these prototype projects may be found at http://www.ehr.nsf.gov/ehr/due/programs/nsdl/projects.asp. While many of these projects focused on what is most easily recognized as collection development, others began to explore organizational and managerial functions of a distributed digital library.

Program elements

In FY 2000 the NSDL program began its first formal funding cycle and has had four to date with proposals solicited in three tracks: Collections, Services, and Targeted Research. The essential features of these tracks are:

- *Collections* – compilation of resources forming a subset of the library's content within a coherent theme or specialty;

- *Services* – development of services that support users, collection providers, and/or the coordinate management of NSDL, and enhance the impact, efficiency, and value of the library; and

- *Targeted Research* – exploration of specific topics (e.g. user studies or investigation of personal annotation systems) that have immediate applicability to one of the other tracks.

To support the coordination and management of the digital library's distributed collections and services, a set of FY 2000 pilot projects in a special track, *Core Integration*, explored models for organizational and technical infrastructure. Based on this work a single *Core Integration* (CI) project began in FY 2001 to execute the initial steps of this activity: i) to implement the primary portal (a "branded destination") through which users will enter the digital library and ii) to establish a suite of core services to access STEM educational resources. Funding supports the organizational and management functions incumbent on the core integration team, implementation of essential user services, and facilitation of community developed practices and policies (including protocols for tagging resources with metadata and development of indexing taxonomies to facilitate searches).

Examples of core user services include:

- maintenance of the primary NSDL portal at http://www.nsdl.org/;

- creation and maintenance of a central metadata repository (for further details, see the section on the NSDL metadata framework below);

- implementation of a search capability built on top of the central metadata repository, using the Jakarta Lucene engine (see http://jakarta.apache.org/lucene/docs/index.html);

- implementation of an initial user authentication capability employing the Shibboleth protocols (http://shibboleth.internet2.edu/) created under the NSF Middleware Initiative; and

- maintenance of news and exhibits features.

A Communications Portal is also available at http://comm.nsdl.org to facilitate sharing of ideas and collaboration among NSDL users and developers. Various public Workspaces are hosted for sharing NSDL information, discussing community and educational issues, and supporting the larger distributed library development effort.

Project characteristics

Projects in the *Collections, Services, and Targeted Research* tracks have been developing and testing various aspects of the NSDL, addressing issues such as quality control, user access and services, intellectual property, evaluation, and models for sustainability. For descriptions of each project from FY 2000, FY 2001, FY 2002, and FY 2003 please see the relevant articles in D-Lib Magazine [11-14]. All awards are listed at http://www.ehr.nsf.gov/ehr/due/awards/nsdl.xls, with each award number linked to its full award abstract. Existing collections efforts include coverage of life sciences, physics, geotechnical engineering, mathematical sciences, several areas of geosciences, chemistry, materials science, anthropology, economics, demography, computer science, statistics, bioinformatics, linguistics, plus several cross-disciplinary collections.

Beyond discipline-based collections thematic projects are growing: e.g. video collections, services for targeted audiences, etc. and NSDL has seen increased involvement of professional societies, which in some cases are hosting the collection. There is also nascent private sector and publisher involvement and numerous formal collaborative projects are underway. Although to date the majority of the approximately one hundred twenty projects are being conducted at institutions of higher education, about a third of these have either an explicit focus on various pre-K to 12 domains, or strong potential for application to that sector, in keeping with NSDL's goal to serve a broad audience. Finally, several targeted research investigations are evaluating user behavior and needs and considering the automated generation of metadata tags and domain specific ontologies. All projects have interdisciplinary teams of principal investigators from a variety of backgrounds, including expertise in the library and information sciences, computer science, digital library research, disciplinary content, and instructional design.

Several active NSDL projects do address engineering content. One focuses on a sub-domain of civil engineering, the "Geotechnical, Rock, and Water Resources Library (GROW)" based at the University of Arizona, 0121691 (see http://www.grow.arizona.edu/index.shtml). A second project is "TeachEngineering - Hands-on Resources for K-12," a collaborative effort based at the University of Colorado, 0226322, 0226191, and 0226236 that supports K-12 teachers seeking to incorporate engineering principles into their curricula (see http://teachengineering.com/). A third project focuses on the needs of the professional engineer, "The Digital Library Network for Engineering and Technology," based at Virginia Tech, 0085849 (see http://www.dlnet.vt.edu/). All three projects have engaged an active set of participants within the engineering education community. Also, it is interesting that these three projects each address a different target audience: the K-12 teaching sector, the undergraduate level, and finally the needs of the professional or life-long learner. Collectively they paint a picture of how the engineering education community can contribute to the development of a national digital library for STEM education. *However, it is clear from even a quick consideration of the larger set of currently funded NSDL projects that there are large domains of engineering that remain unaddressed.*

Since the program's inception two NSF directorates, the Directorate for Geosciences (GEO) and the Directorate for Mathematical and Physical Sciences (MPS) have provided significant co-funding on numerous projects, illustrating the NSDL program's facilitation of the integration of research and education, an important strategic objective of NSF. In recent funding cycles the Directorate for Biological Sciences (BIO) and the Directorate for Social, Behavioral, and Economic Sciences (SBE) have also provided modest amounts of co-funding. As the program continues to develop there are natural opportunities to broaden NSDL's disciplinary coverage in areas of interest to other NSF supported disciplines; engineering presents one notable area of opportunity. The program has also co-funded a number of international digital library research efforts that feature a significant educational component. While NSDL has no formal international funding agreements, this area bears attention given that the Internet transcends geographic boundaries, and educational goals – particularly in STEM disciplines – cut across cultures.

NSDL metadata framework

To facilitate resource discovery and sharing within a digital environment, librarians and information scientists have developed the concept of metadata, which has its roots in traditional library cataloging services, in particular machine readable cataloging. The NSDL information architecture supports several metadata record formats, with Dublin Core recommended at a minimum, see http://dublincore.org/. In addition, all new and continuing content contributors should supply records for harvesting via the Open Archives Initiative (OAI) protocol, see http://www.openarchives.org/OAI/openarchivesprotocol.html. To provide better educational context for users, contributors of item-level metadata should provide information corresponding to *Audience* and *educationLevel* (the elements in Dublin Core) and developers should use a currently available controlled vocabulary for the *Subject* entry or be willing to expose their vocabulary publicly. For pre-K to 12 focused collections, it is recommended that resources be correlated to state or national standards and that information be mapped to the *conformsTo* refinement for *Relation* in Dublin Core. Finally, since Qualified Dublin Core carries this information most effectively, it is recommend that projects expose Qualified Dublin Core for harvesting via OAI in addition to the OAI mandated Simple Dublin Core. For further information the NSDL Metadata Primer http://metamanagement.comm.nsdl.org/outline.html and the Institute of Museum and Library Services document, "A Framework of Guidance for Building Good Digital Collections," http://www.imls.gov/pubs/forumframework.htm should be consulted.

New program components

In FY 2004 the NSDL program will continue to support projects in the *Services and Targeted Research* tracks, but has replaced the *Collections* track with a *Pathways* track. Within the *Services* track two particular types of projects are strongly encouraged: 1) *Selection services* and

2) *Usage development workshops*.

- *Pathways* projects will assume a stewardship role for the educational content and/or the services needed by a broad community of learners.

- *Selection services* projects will focus on increasing the amount of high-quality STEM educational content known to NSDL.

- *Usage development workshops* will promote the use of NSDL and its resources by various communities of learners.

These three elements reflect an appropriate expansion in emphasis for NSDL from its initial (and necessary) collecting of educational resources, materials, and other digital learning objects, towards enabling learners to "connect" or otherwise find pathways to resources that are appropriate to their needs. A rough analogy for a "pathways" project might be found in the disciplinary branch libraries often associated with a traditional library system, or alternatively the neighborhood libraries that form a public network and that might cater specifically to the needs of the local citizenry. Projects in these three emphasis areas will develop both the capacities of individual users and the capacity of the larger community of learners to make use of and contribute to NSDL. In addition, workshop projects will permit the study of user information-seeking behavior and user interaction with specific NSDL content. The FY 2004 NSDL proposal deadline is April 14, 2004. For further information prospective proposers are encouraged to visit http://www.ehr.nsf.gov/due/programs/nsdl/.

Implications for engineering education

NSDL will differ from the physical library in at least three ways. First, the variety of content itself (most of it "born digital") will be far greater in NSDL than in the physical world, e.g. virtual laboratory modules, simulations or animations, and multimedia in general. Second, the interactions the user can have with material are far richer. For example, the ability to execute rapid searches across multiple collections; or the ability to pull disparate smaller grained resources from different collections and assemble them to create something new, which can then be contributed back to the NSDL; or steering a remote piece of instrumentation. Third, a user may interact with other users in new ways. For example, learning in a collaboratory with others in remote locations, yet in real-time. Or annotating the work of others and engaging in dialogue with the creator of a learning module to improve its features (imagine scribbling a note in the margin of a book and leaving it in hopes that the author would happen on that library and look through that book!)

These differences will enable engineering educators to use materials and tools for learning supplied by cooperating resource collections and services. For example, undergraduates could i) access a case study at one site of how engineering design principles are employed in bridge and roadway construction, ii) combine it with finite element models and computational and visualization tools from another collection, iii) analyze the virtual system's ability to withstand earthquakes of varying type and strength, and iv) display these against archived geographical information system data from previous tectonic events relevant to the location. Of course this vision of reusing, repurposing, and repackaging resources and the flexible assembly of curricular and learning modules from component pieces cannot be realized without consideration of serious intellectual property issues. But advances in digital rights management offer the potential of tracking usage in a way that reputation can accrue to creators. Certainly this has bearing on how the engineering education community formally recognizes scholarship.

Communication and collaboration capabilities accessible through and in some cases supported by NSDL offer the engineering education community the opportunity to foster the creation of team learning environments that pervade the entire curriculum. These could certainly extend outside of the formal campus confines to include students from other campuses, practicing engineers and scientists, and management. In some cases these could be formal teams that persist for specific times and goals, and in others they may be informal and persist over longer times. Indeed learning communities can form that are no longer restricted by geography, but instead defined by interest. Virtual collaborative work areas will support learning in interactive networked laboratories, synchronous or asynchronous sharing of remote instrumentation, and exploitation of simulated or virtual environments. Opportunities for the development of a rich array of these capabilities certainly present themselves.

Finally, customization features of the digital library will enable users of widely different backgrounds, expertise, and needs to maintain personalized interfaces to the educational resources and services of NSDL. For example, an engineering educator will be able to input a profile to specify a search for inquiry-based laboratory resources that i) have been reviewed by fellow faculty, ii) are "mapped" or otherwise associated with ABET outcome goals, iii) contain embedded assessment tools, and iv) feature interactive visualizations of the phenomenon under study. Students will be able to take a hand in creating learning materials themselves, perhaps as mentors to younger students or as teaching assistants, and these "products" may be retained in electronic portfolios or persistent e-carrels. Likewise professional engineers may be able to access continued certification opportunities and retain previous resources for reference.

References

[1] Information Technology: Its Impact on Undergraduate Education in Science, Mathematics, Engineering, and Technology (NSF 98-82), April 18-20, 1996. Available at <http://www.nsf.gov/cgi-bin/getpub?nsf9882>.

[2] Developing a Digital National Library for Undergraduate Science, Mathematics, Engineering, and Technology Education, NRC workshop, August 7-8, 1997. Available at <http://books.nap.edu/books/0309059771/html/R1.html>.

[3] Report of the SMETE Library Workshop (NSF 99-112), July 21-23, 1998. Available online at <http://www.dlib.org/smete/public/report.html>

[4] Serving the Needs of Pre-College Science and Mathematics Education: Impact of a Digital National Library on Teacher Education and Practice, NRC workshop, September 24-25, 1998. Available at <http://www.nap.edu/catalog/9584.html>.

[5] Digital Libraries and Education Working Meeting, January 4-6, 1999. Available at <http://www.dli2.nsf.gov/dljanmtg.pdf>.

[6] Portal to the Future: A Digital Library for Earth System Education, workshop report, August 8-11, 1999. Available <http://www.dlese.org/>.

[7] Mogk, David W. and Zia, Lee L. "Addressing Opportunities and Challenges in Evaluation and Dissemination through Creation of a National Library for Undergraduate Science Education." Invited Symposium in Proceedings of the 31st Annual Meeting of the Geoscience Information Society, October 28-31, 1996, Denver, CO (1996). Available <http://gdl.ou.edu/rp1.html>.

[8] Wattenberg, Frank. "A National Digital Library for Science, Mathematics, Engineering, and Technology Education." D-Lib Magazine, October 1998. Available at <http://www.dlib.org/dlib/october98/wattenberg/10wattenberg.html>.

[9] Wattenberg, Frank. and Zia, Lee L. "Technology-enriched Learning of Mathematics: Opportunities and Challenges", in Learning Mathematics for a New Century, NCTM 2000 Yearbook, NCTM, Reston, VA 2000.

[10] Zia, Lee L. "Growing a National Learning Environments and Resources Network for Science, Mathematics, Engineering, and Technology Education: Current Issues and Opportunities for the NSDL Program." D-Lib Magazine, March 2001. Available at <http://www.dlib.org/dlib/march01/zia/03zia.html>.

[11] Zia, Lee L. "The NSF National Science, Mathematics, Engineering, and Technology Education Digital Library (NSDL) Program: A Progress Report." D-Lib Magazine, October 2000. Available at <http://www.dlib.org/dlib/october00/zia/10zia.html>.

[12] Zia, Lee L. "The NSF National Science, Technology, Engineering, and Mathematics Education Digital Library (NSDL) Program: New Projects and a Progress Report." D-Lib Magazine, November 2001. Available at <http://www.dlib.org/dlib/november01/zia/11zia.html>.

[13] Zia, Lee L. "The NSF National Science, Mathematics, Engineering, and Technology Education Digital Library (NSDL) Program: New Projects in Fiscal Year 2002." D-Lib Magazine, November 2002. Available at <http://www.dlib.org/dlib/november02/zia/11zia.html>.

[14] Zia, Lee L. "The NSF National Science, Mathematics, Engineering, and Technology Education Digital Library (NSDL) Program: New Projects in Fiscal Year 2003." D-Lib Magazine, March 2004. Available at <http://www.dlib.org/dlib/march04/zia/03zia.html>.

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