

NSF's NSDL Program: An Overview of its History, Progress, and Promise

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During the latter part of the 1990s the National Science Foundation (NSF) provided support for a series of workshops to explore and capture the perspectives of a wide variety of potential stakeholders about what a national digital library for science, technology, engineering, and mathematics (STEM) education might “look like,” how it might be supported, who would be the audience, and how it might be sustained. The proceedings of these workshops, their recommendations, and other commentaries were documented in accompanying reports and monographs [1-8]. From these efforts a picture emerged of the digital library as a “learning environments and resources network” for STEM education, with three central features:

- it should meet the needs of learners, in both individual and collaborative settings;
- it should enable dynamic use of a broad array of materials for learning primarily in digital format; and
- it should be managed actively to promote reliable anytime, anywhere access to quality collections and services, available both within and without the network.

These exploratory workshops had their roots in internal concept papers in the mid-1990s within the NSF Division of Undergraduate Education (DUE) that argued two key points. First, coinciding with the emergence of the World Wide Web (recall that as of early 1995 the Mosaic browser had only just been released and Netscape was not even a company!) there was an emerging research area being supported by the NSF Division of Information and Intelligent Systems (IIS) called the Digital Libraries Research Initiative (DLI) that was tackling challenging questions regarding organization, search, and discovery of digital content – diverse both in its forms (text, images, audio, video) and its sources (formally published and self-published, open-source and proprietary, and all increasingly “born digital” [9]). Second, the education domain – in particular, undergraduate STEM education – offered a particularly fertile area where such research results could find meaningful application. Since the DLI research program had by that time expanded into its second stage, the NSF Digital Libraries Research Initiative – Phase 2 (DLI-2), DUE conducted a modest funding effort for prototype projects as a special emphasis area under the umbrella of DLI-2, targeting just the undergraduate education sector. Based on the positive response of the community to this funding opportunity and also buoyed by interest shown from staff at the Office of Science and Technology Policy, NSF initiated the National Science, Technology Engineering, and Mathematics Education Digital Library (NSDL) program in fiscal year (FY) 2000 to create,

¹ The views expressed in this article are entirely those of the author and do not reflect official NSF statements or positions.

develop, and sustain a national digital library supporting STEM education at all levels – pre-K to12, undergraduate, graduate, and life-long learning. An article in *D-Lib Magazine* details the original vision of the program, early assumptions, and speculations about its growth [10].

In viewing the program since its inception, it is useful to consider developments during two four-year cycles. The first spanned fiscal years 2000-2003, which saw projects funded in each of four tracks:

- *Collections* – to aggregate and actively manage a subset of the digital library’s content within a coherent theme or specialty;
- *Services* – to develop services that support users, collection providers, and/or the Core Integration effort and enhance the impact, efficiency, and value of the digital library in its fully operational form;
- *Targeted Research* – to explore specific topics that have immediate applicability to one of the other three tracks; and
- *Core Integration (CI)* – to coordinate a distributed alliance of resource collection and service providers, to ensure reliable and extensible access to and usability of the resulting network of learning environments and resources, and to maintain the digital library’s primary portal.

During these earlier years of the program, before “there was a there, there” that could be identified as NSDL, projects in the first three tracks focused primarily on developing and testing various aspects of the emerging network, addressing issues such as quality control, user access and services, intellectual property, evaluation, and models for sustainability. In addition, projects explored development of collections in new content domains; new value-added library services with which to validate operating capabilities; and targeted research in several areas including identification of user needs, automated generation of metadata tags, analysis of user information-seeking behavior, and development and use of domain specific ontologies [11-14]. Award numbers are given and can be used to view the complete project abstracts on the NSF award search page, <http://www.nsf.gov/awardsearch/> (last accessed 08/2008).

To support the coordination and management of the digital library’s distributed collections and services, a set of FY 2000 pilot projects in the fourth track, *Core Integration*, explored models for organizational and technical infrastructure. Based on this work a first stage *Core Integration* (CI) project took the initial steps of this activity in FY 2001: i) to implement the primary portal (a “branded destination”) through which users would interact with the digital library’s network of resources and ii) to define a suite of core services to access STEM educational resources; the CI activity then began full-fledged operations in January 2003. Funding has supported 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).

During this first phase of NSDL collections development took place in a variety of areas, including: various engineering disciplines, life sciences, physics, mathematical sciences, sub-areas of geosciences, chemistry, materials science, anthropology, economics, demography, computer science, statistics, bioinformatics, linguistics, plus cross-disciplinary collections. In addition, the program saw a growth in the number of thematic projects: e.g. video collections, services for targeted audiences, etc. A very positive development that has only continued to strengthen as the program has evolved was the involvement of professional societies, in some cases as the fiscal agents for NSDL awards, and in other cases as a principal partner. Towards the latter part of this initial phase the program also began to see the growth of nascent private sector interest (some awards were made to small for-profit concerns) and the involvement of publishers both from the not-for-profit and for-profit sectors. An important hallmark of many projects was their funding and execution as so-called “collaborative awards.” These formal collaborative projects brought together highly interdisciplinary teams of faculty bringing disciplinary expertise, personnel from emerging schools of information and library science, and practicing librarians from a variety of institutions and organizations. Finally, an excellent pattern of involvement arose featuring principal investigators whose main focus lay in the experience and expertise regarding the pre-K to 12 sector. Indeed, of the many projects funded during the first four-year cycle of the program, forty-three had explicit pre-K to 12 linkages and another twenty-eight had strong potential for application to this sector.

The second four-year cycle of NSDL began in FY 2004 when the program replaced the *Collections* track with a new *Pathways* track. These projects were intended to assume a stewardship role on behalf of NSDL for the educational content and/or the services needed by a broad community of learners. In addition, such projects would maintain criteria and mechanisms to identify, select, annotate, and generate metadata for high-quality and relevant digital content; sustain the currency of the aggregated educational resources; and preserve the usability of digital content as the underlying information technology systems evolved.

The program also began to introduce an element of prescriptiveness within the *Services* track by strongly encouraging two particular types of projects: 1) *Selection services* and 2) *Usage development workshops*:

- *Selection services* projects would focus on increasing the amount of high-quality STEM educational content known to NSDL; and
- *Usage development workshops* would promote the use of NSDL and its resources by various communities of learners.

These three new elements: *Pathways*, *Selection services*, and *Usage development workshops* were deliberate programmatic moves that reflected 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.

In FY 2005 the program continued support for projects in all of these areas of emphasis. Early *Pathways* projects had definite disciplinary themes, e.g. mathematical sciences,

biological sciences, computational sciences, engineering, and physics. But the original vision of the *Pathways*, as embracing more thematically defined content or otherwise serving the needs of an audience that would have learning needs that cut across disciplines, was also borne out with projects serving, for example, the community college sector in applied mathematics and science, and the need of K-12 teachers to have access to rich media resources either in their own classes or as the basis for professional development. The FY 2004 projects and FY 2005 projects also began developing both the capacities of individual users and the capacity of the larger community of learners to make use of NSDL. And the workshop settings were expected to permit the study of user information-seeking behavior and user interaction with specific NSDL content.

In FY 2006 the program solicited another round of proposals in the *Pathways* track. However, due to budgetary factors that had led to constraints in the overall NSDL program budget the program only accepted proposals in a limited sub-track of *Services* termed the “Integrated services” sub-track. In addition, requests for small amounts of supplemental funding from current projects in the *Services* and *Targeted Research* tracks, or earlier *Collections* projects were solicited. These requests for supplements proposed to extend or enhance the “parent” project’s ongoing work and activities so as to integrate with other projects or the *Core Integration* activities, to reach a larger audience, or improve the functionality and capability of user services. In FY 2007 the program solicited another set of proposals in the *Pathways* track, a set of proposals in a specific component (“Integrated services”) of the *Services* track, and expanded the previous year’s option to submit proposals for supplements into a full-fledged “*Small grants*” track.

The move to formally offer such a “small grant opportunity” was intended to capitalize on an important decision that took place on the technology front as the earlier “metadata-centric” orientation of NSDL’s underlying information architecture was completely overhauled and replaced by a “resource-centric” NSDL Data Repository that exploited the emergent Fedora architecture for repository management. Specifically, metadata or “data about data” remains an important concept in information organization that has its origins in the perspective of the catalog librarian (think of card catalog records). Thus, in the early Web environment consisting solely of distributed collections, the concepts of i) metadata harvesting (based on Web collections providing metadata about their holdings) and ii) a resulting union catalog of records formed the basis of an appropriate approach to digital libraries. However, with the emergence of “Google-like” search services and usage patterns of the Web by general users (e.g. annotating, sharing, and recommending) an emphasis has grown on representing relationships among resources and their metadata, and to associate content with all descriptions, annotations, and other resource selections so that context, in particular educational context can be captured. Concurrent with these developments digital library researchers were working to create a powerful repository management approach and systems application called Fedora that provides full and flexible support for these capabilities, see <http://www.fedora-commons.org/> (last accessed 08/2008). Therefore, against the background of the new Web 2.0 paradigm characterized by social networking and user participation in content and community creation, there was a realization that an investment in a new and broader approach to organizing NSDL’s metadata and other digital assets would position NSDL to incorporate the new technologies and practices of social media and introduce a vital

Web 2.0 component to NSDL.

From the NSDL program's perspective the small grants opportunity was thus formalized in the recognition of the possibility that relatively small investments could support projects of relatively modest funding but very high impact on the larger "ecosystem" of NSDL projects by exploiting the availability of Web 2.0 tools and approaches. Already the benefits of this technology upgrade have been felt, as NSDL's wiki and blogging systems grow in use. Since this project type has still received only a small number of proposals, the program has included support for projects in these areas during its FY08 cycle.

Collaborations and Partnerships

The NSDL program is an unusual program for NSF in that its projects are engaged in building an enterprise much larger than the object of any one award. Indeed, the ultimate success of the program rests at least partly on the degree to which its projects embrace a collective sense of identity and mission. To foster this goal, an initial grantees meeting was held at NSF in late September 2000 for the purpose of introducing all projects to one another, with an eye towards identifying potential areas of collaboration and partnership. Attendees demonstrated a great sense of passion and responsibility, and notably, they self-organized into various working groups around topics and issues of joint concern. Many of these working groups have remained quite active since this first meeting and more information may be found at <http://nsdl.org/about/?pager=organization> (last accessed 08/2008). Threaded discussions continue, and the broader STEM educational community has always been encouraged to join these.

This theme and practice of collaboration has grown steadily as the NSDL program has evolved and there are several compelling examples of early collaborations that have grown into genuine partnerships over time. Perhaps one of the most mature examples is the active cultivation of relationships with major publishers. Early work in the NSDL Sustainability Committee, see the Events Archive of this committee's work available at <http://sustain.comm.nsdl.org/?pager=145> (last accessed 08/2008) explored various prospects for sustainability of the NSDL enterprise with representatives of both the commercial and not-for-profit publishing communities participating actively in these meetings. Over time agreements between a number of major publishing concerns and NSDL have been entered into to share metadata and in some cases full content in exchange for digital librarianship expertise and services and extension of reach into digital markets. A number of the most notable agreements include publishing houses such as Macmillan/McGraw-Hill, John Wiley and Sons, and National Academy Press; and more recently NSDL partnerships have extended into new media opportunities with the placement of NSDL content on iTunes U at <http://nsdl.org/iTunesU/> (last accessed 08/2008).

Another particularly strong set of partnerships has grown with sectors of the K-12 community.

- Project Tomorrow, a non-profit organization, has partnered with Utah State University and NSDL Core Integration staff to implement Project TestDrive: NSDL. Through its

well-known NetDay Speak Up survey, Project Tomorrow has collected the opinions on education and technology issues from over 850,000 K-12 students, teachers, and parents in all 50 states. In this emerging partnership Project Tomorrow has begun to recruit teachers and students from almost 100 schools nationwide, who are selecting, evaluating, and using online resources from NSDL.

- To illustrate the potential for NSDL to offer services at the school district level, the Curriculum Customization Service project has engaged in a partnership with the Denver Public Schools to integrate high-quality NSF-funded science curriculum, NSDL specific resources, and school district-developed resources into interactive, concept-based Teacher's Guides, delivered directly to teachers through their school portal. Materials, professional development, and support services are being provided for 120 teachers, who educate over 9000 students each year. Moreover, this effort links resources from NSDL to strand maps of concepts and to state and national standards, which in turn enables all classrooms in the system to access content customizable to their needs on day-to-day or even moment-to-moment basis.
- A nascent collaboration from which a more substantial partnership may emerge has involved a number of NSDL projects working on the complementary problems of i) harmonizing educational standards among state, regional and national frameworks and ii) cataloging of educational resources according to such science education standards. In particular, discussions are now underway between the Council for State Science Supervisors (CSSS) and staff from the Alignment Standards Network and NSDL CI teams on moving the use of several cataloging and standards alignment services into the regular workflow of practicing science teachers and specialists. This will enable teachers not only to search for resources using either their home state standards or the national standards, but also to share educational resources easily from anywhere in the country.

A last example illustrates the emergence of “utility-like” application services that NSDL is in a position to offer to consortia of information providers. Late in summer 2007, NSDL began a partnership with the Colorado Alliance of Research Libraries (CARL) through which CARL has adopted the NSDL Data Repository and its Fedora-based technology platform to provide distributed collection management for its eleven member institutions. This work has begun with the creation, storage, management, and delivery of very large image collections from the member libraries, with a key public benefit of the project that it enables these resources to be accessible to all school districts and public libraries across Colorado and Wyoming. This initial effort points the way towards the provision of more extensive repository services for the text, image, and video resources of the Alliance. NSDL is also cultivating a similar type of relationship with the Southern Regional Education Board, a consortium representing higher education institutions across sixteen southeastern states.

Challenges and Future Directions

As the program enters its third four-year cycle of projects it can look back on substantial progress on a number of fronts some of which have been described above. However, challenges still remain. Some reflect shifting trends and the potential for expanding, if not

changing roles within the educational community; and some represent important issues that projects must address.

First, the traditional roles and relationships to one another of faculty and librarians are likely to change on campuses. Faculty, as producers of scholarship – all of which is now essentially “born digital” – will need to develop awareness of, if not base level expertise in issues of library management: e.g., cataloging, metadata tagging, and preservation. As a result, library staff are likely to find that their presentation of externally produced resources to campus users will be balanced by a need to convey to the external world the products of faculty efforts on campus. Certainly the explosion of user-generated content with accompanying social bookmarking and tagging tools is serving as a driver for this trend. And there are similar implications for teachers and librarians in the pre-K to12 sector. As these trends continue to grow, they will certainly have important implications for graduate programs, from where the next generation of faculty and library and information specialists will come. More than just a matter of disseminating information about these advances, this broader engagement will require systematic and systemic effort to help different audiences learn a new language, with faculty needing to understand issues of librarianship and librarians growing to appreciate faculty roles. Of particular interest is the challenge these changing roles will place on the future structure and content of graduate and professional school programs. Similar issues bear on the future of museums and other informal learning venues and the professionals who work in them.

Second, it is vital that the educational community (and NSDL is positioned well to provide the appropriate leadership) focus attention on evaluating the impact on learning that results from the increased access to resources and data made possible by digital libraries. To date both issues of quality and efficacy reside “locally” in the hands of NSDL resource providers, reflecting the distributed nature of NSDL. For example, individual NSDL Pathways projects implement various approaches to peer review. Here there is also room for NSDL Services projects to implement annotation systems to enable more informal community reviewing mechanisms. It is also possible that in the future the NSDL program itself may call specifically for funding tracks that would support projects to assess student learning in the presence of networked educational resources. Closely related to this issue is the need to develop appropriate “metrics” to capture both the degree of reuse, repurposing, or repackaging of digital material and to assess the value of such activities. Moreover, deeper understanding and satisfaction of end user needs that move beyond pure searching for factual “data” to more nuanced semantically imbued sense making is needed. Here the promise that increased customization holds must be balanced against privacy concerns, since learners must be willing to reveal more of themselves in order to gain the benefits of personalized profiles.

Third, the question still remains of how to compensate creators of content for their efforts. Contributions of “fine-grained” content (e.g., short applet tutorials or simulators) and creation of mashups can gain peer recognition; and in open source/community source software efforts such recognition has proven suitable, functioning as a legitimate “currency” for compensation. Whether or not the same can hold true for the continued creation of educational content is still unclear, but the promise does exist. NSDL offers a way to make

such innovative content available through locally maintained digital repositories and shared through a broad network of contributing providers. While producers have primarily been from the higher education community, the evolving capabilities and ease for reusing and reforming content are broadening participation in this activity rapidly. However, key issues will continue to center on questions of authenticity, the certification of expertise, and mechanisms and practices for attribution of creation. One excellent source of information on the latter is the Creative Commons site <http://creativecommons.org/> (last accessed 08/2008) that details a spectrum of possibilities ranging between full copyright and public domain. While the NSDL program does not have an official policy on intellectual property (NSF itself is not a policy-making agency), the NSDL community of projects and users harbor in large measure a commitment to the values of open access, even as there is a recognition that “for free” and “for fee” can co-exist.

Finally, two additional opportunities merit the attention of the NSDL program. One is in the area of international collaboration and the other is in the area of promoting collections and services development in content domains outside of science, mathematics, engineering, and technology education. Although both fall outside the nominal purview of the NSF it is well within the responsibility of NSDL and NSF to seek to partner with other organizations both at the federal level and internationally to make progress on these fronts.

How might the capability to address the multiple challenges identified above be mounted and sustained? One approach would be to place responsibility in the hands of a non-profit organization to provide leadership for the science, science education, and more general scholarly community to meet these challenges. Through a public funding effort educational institutions would receive initial support to connect to such a (virtual) organization as a member institution for several years. However, grants would not be for physical connectivity, but rather:

- to build capacity to make locally developed educational resources and services – institutional repositories – available to a wider audience via the NSDL (gaining access in return to the larger collective body of resources and services), and
- to support local teacher/faculty development activities to engage educators in how to make use of the new capabilities of NSDL and the resources to which it provides access.

Continued membership would fall on each individual institution, and (eventually) a relatively modest annual fee multiplied across interested institutions of higher education and local school districts could generate a significant source of self-sustaining revenue. As the “network effect” took hold – with the value of the network increasing as more members join – such a strategy would enable NSF and other funders to transition support for this facility to a community-based mechanism.

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