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September 10, 2007

Dear Friend of NSDL,

In early August of this year, the National Science Board of the National Science Foundation released the draft version of a new report: "A National Action Plan for Addressing the Critical Needs of the U.S. Science, Technology, Engineering, and Mathematics Education System".

NSDL was mentioned twice, as both a repository for STEM materials and as a means of dissemination. Those basic functions are important but they do not do justice to the real extent of NSDL activities and capacities in support of STEM education.

We prepared the attached comments so that the NSB and NSF could more fully understand what their investment in NSDL has produced.

The final version of the report will go to the NSB for approval at their May meeting. We hope it will more completely reflect the reality of NSDL and the extensive NSDL community.

Sincerely,

A handwritten signature in black ink, appearing to read 'Kaye Howe', written in a cursive style.

Kaye Howe
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THE NATIONAL SCIENCE DIGITAL LIBRARY

Response in Support of the National Science Board Action Plan for STEM Education

Submitted by
The National Science Digital Library

August 30, 2007



THE NATIONAL SCIENCE DIGITAL LIBRARY

About This Document

In August 2007, the National Science Board released the first draft of *A National Action Plan for Addressing the Critical Needs of the U.S. Science, Technology, Engineering, and Mathematics Education System*. Based upon the recommendations of an advisory Commission on 21st Century Education in Science, Technology, Engineering, and Mathematics, the draft was made available for broad review. This document contains the response submitted by the National Science Digital Library during the public comment period.

About the National Science Digital Library

The National Science Digital Library (NSDL) is an online library of exemplary teaching and learning resources for science, technology, engineering, and mathematics education at all levels. NSDL facilitates collaboration and engages stakeholders across public, private, K-12, university, and government organizations to provide effective management and delivery of digital resources, tools, and services.

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Introduction

In August 2007, the National Science Board released the first draft of *A National Action Plan for Addressing the Critical Needs of the U.S. Science, Technology, Engineering, and Mathematics Education System*¹. The National Science Digital Library (NSDL),² a major STEM education asset of NSF cyberinfrastructure, is mentioned twice in the draft report. The first mention is as a repository for STEM materials and the second as a means of dissemination. NSDL performs both those functions now, not only for NSF, but for a large range of other organizations and individuals.

In this response, we detail how NSDL goes beyond that basic support. We describe a significant, highly distributed, STEM education network which leverages the skills and resources of partners from, for example, professional societies, publishers, and major organizations like the American Association for the Advancement of Science (AAAS) and the National Science Teachers Association (NSTA), to state level organizations. We long ago made the decision to leverage trusted networks and put NSDL at the user's point of need.

We have often found that digital libraries are regarded as little more than web sites, or the latest incarnation of “educational technology”—the failed promise of a pedagogical Rosetta Stone. What follows should give the National Science Board and others a clear understanding of the innovative but well-grounded support NSDL provides for STEM education.

Building NSDL, the Organization

Since 2000, NSDL has focused on this vision: to effectively organize and deliver a broad and deep selection of online STEM education resources while capitalizing on the intellectual promise of active community participation. As a digital library for education, NSDL began by building on early digital library research that focused on creating the infrastructure of online repositories. It has since evolved to an organization that facilitates collaboration and engages stakeholders across public, private, K-12, university and government organizations to provide effective delivery of digital resources for all levels of STEM education.

Like any maturing organization, NSDL has had its course corrections and opportunities to reconceive the organization and its directions. Looking back, there is little surprise that coordination of multiple projects was a primary

challenge of the early days. However, to successfully meet educator needs, NSDL had to move beyond integrating the disparate results of projects funded by the NSF, to building a community that could deliver on the promise of a broad and deep selection of materials for learners at all levels.

Over the years, NSDL has learned that success in managing such coordination-intensive endeavors requires building technical infrastructure while supporting community collaboration, outreach to educators, and broad dissemination efforts. Building NSDL has focused on creating both technical and organizational capacities including: developing sophisticated technologies to support the organization, description and dissemination of STEM education resources; building effective networks of partners to leverage existing efforts and extend the reach and impact of NSDL; using both traditional and cutting edge dissemination methods to engage NSDL users; and building an organization capable of managing the breadth of such distributed activities.

Developing and Operating Infrastructure

As with any service provider, a day-to-day organization is required to build and operate the library infrastructure, and provide user and partner support. Beyond providing basic library operations, the ultimate challenge in building NSDL is getting the right information to the right person at the right time. In reality, useful information is always situated in a larger knowledge context. To best serve educators, NSDL decided to move beyond a collection-based repository that managed traditional library metadata, and create a repository to manage context that connects educational resources to related information—such as annotations, educational standards, news, source information, images, user commentary, and reviews. As a result, NSDL is harnessing the technical aspects of the cyberinfrastructure it has built to empower community-driven enhancements in STEM teaching and learning.

Using Fedora,³ NSDL developed the NSDL Data Repository (NDR) to help manage such complex information. Fedora is an open-source middleware that offers NSDL the flexibility to support a variety of developing technologies. The library has chosen a resource-centric approach to building the repository, where resources provide the anchoring point for linking together multiple pieces of descriptive information. Fedora research and development was originally funded by DARPA and the National Science Foundation, supported by the Andrew W. Mellon Foundation, and a new initiative called Fedora Commons has been funded by the Gordon and Betty Moore Foundation.

With the NDR, NSDL distinguishes itself from web search engines by adding value to existing web-based resources, providing educational context around those resources, and enriching them with new information and relationships that express the usage patterns and knowledge of the STEM education community. NSDL has become much more than a search engine for accessing materials; it is a means for information collaboration and accumulation by the broader community.

Unlike traditional libraries with physical holdings, NSDL aggregates community-contributed information about resources, but does not typically hold actual content. NSDL provides services such as an OAI interface and a repository API to assist the community in providing information to the library about their resources. Because NSDL content is held across a distributed network of sites, a community sign-on system is being deployed to help users navigate across the NSDL network more easily as they review and use resources described in NSDL. Providing a range of services and options helps lower the barriers to community participation.

Supporting Distributed Library Building

The NSDL program held its first formal funding cycle during FY 2000. From the beginning, it was envisioned as a collective effort to provide access to a distributed network of resources. By FY 2001, 29 projects had already completed their first year of work in building collections and services, or performing digital library research. In parallel, NSDL was also building infrastructure and developing standards as these early projects were completing their period of performance, leaving little opportunity to collaborate on how these joint activities might be integrated to serve the NSDL mission. Over time, NSF recognized that the original NSDL granting tracks did not best serve the primary goal and responsibility to produce a library of coherent collections, services, and research.

In response, NSF initiated NSDL Pathways in an FY 2004 solicitation. Pathways⁴ are discipline-specific or audience-specific partnerships providing access to resources and services that are developed and managed by institutions with proven expertise in serving their target audiences. The Pathways represent a good focusing strategy because they: 1) provide stewardship for the educational content and services needed by major communities of learners; 2) provide in-depth knowledge of educational needs of that community, and 3) bring broader community participation in NSDL through their partnerships. To ensure success,

NSDL developed a signed Memorandum of Understanding with the Pathways to clarify the administrative and development activities needed to improve the library holdings and services, as well as to drive increasingly compelling collaborations that address larger NSDL strategic goals.

Pathways themselves are leveraging broad networks of partners and coordinating the efforts of STEM education stakeholders including 29 educational institutions and foundations in 18 states, and 46 professional societies and organizations. They focus on disseminating information into the classroom at a variety of educational levels from K-12 to higher education including community colleges and informal learning. They are also seeking solutions to bridge overlapping needs as students make the transition from high school to undergraduate studies. As NSDL and its Pathways respond to user needs, we are gaining inroads into educator use. NSDL.org and selected Pathways sites reported approximately 4 million visits in the last year, ending May 2007.

The Pathways represent a successful strategy to deliver the right information to the right audience. They have been successful in tapping the knowledge of a deep network of STEM stakeholders in scaling up the library across audiences and disciplines. By focusing within audience and disciplinary areas, they ensure NSDL responds to specific requirements within those communities and ultimately connects users to the most appropriate resources for their educational needs.

Leveraging Networks of Partners

Of course, the Pathways represent only a portion of STEM education stakeholders. NSDL has engaged in building additional partnerships with organizations that include significant ties to STEM education, strong national or regional reach, and clear needs for NSDL services and collaborative development that meet common goals. Successful collaborations require clear value propositions for potential partners. NSDL's value lies in multiple areas: a means to deliver resources for broader dissemination; a place to find quality resources for reuse; an opportunity for participating in extended outreach and communication activities; a service for building local repository infrastructure; a source of teacher professional development; and a mechanism for iterative feedback loops between research and education.

These growing collaborations include professional societies, state education groups, STEM education organizations including informal learning institutions, NSF programs, and scholarly publishers. They require coordination of

stakeholders with differing priorities and at different stages of their own organizational lifecycles. To ease integration efforts, the NSDL community has developed policies, standards and best practices to help knit together these development activities, and ongoing work is helping to ensure community adoption and adherence.

Increasing the number of partners engaged with NSDL has improved the efficiency and reach of NSDL. It also helps organize several distinct efforts aimed at improving STEM education by providing common technical infrastructure, tools, standards for sharing information, and best practices that enable effective collaboration. An additional effect of NSDL's partnership building has been the emergence of brand value for NSDL, synthesized from the positive reputation of NSF and the weight of each partner's brand, as well as from a track record of work well done to-date. NSDL is now being viewed within the education community as a locus of quality STEM education materials and services, and as a point of contact representing the broader education efforts of the NSF itself. As the NSDL brand grows stronger, it increases the value proposition for partners to collaborate with the library and enables NSDL to expand its impact in STEM education.

Disseminating Results to Educators

As NSDL has matured, and as the nature of online resource discovery has evolved in a world where Google is a verb, the library has learned valuable lessons about reaching educators through its own efforts and those of Pathways and other partners. These lessons have shaped current strategies for expanding awareness to increase usage, sharing best practices, providing professional development opportunities, and supporting teachers in their classroom practice.

One key tenet of NSDL's Outreach programs is the importance of engaging educators "where they are" rather than requiring time-crunched teachers to adopt new habits for information discovery and curriculum enhancement. By embedding access to NSDL resources within the channels that teachers, faculty, and librarians are already using, NSDL can leverage the power of trusted networks and ultimately make the library more useful. The Pathways are one application of this strategy, as they connect their professional society members and other existing users to the broader resources of the library as a whole. NSDL has also been actively building partnerships beyond the Pathways to extend its outreach while simultaneously adding value to the work of other STEM stakeholder organizations.

When NSDL first launched public access to the library and began to promote NSDL and its partners within the educational community, it quickly ran up against barriers related to teachers' comfort level with educational technology that needed to be addressed before widespread usage of the library could be achieved. As a result, building knowledge and skills around the effective integration of digital learning materials in the classroom became a primary goal of NSDL's educational outreach efforts. In the past year, this goal has further expanded to include building capacity within the broader context of 21st Century skills.

NSDL also recognized that the NSF-funded projects creating the lesson plans, topical collections, data visualizations, and other digital learning tools cataloged by the library often have insufficient personnel time and expertise to effectively conduct outreach to their target audiences. As a result, NSDL's brokering, facilitation, and integration roles have become of critical importance to the community of grant-funded and other non-profit providers of STEM education resources. NSDL is building partnerships to support both the dissemination of scientific research to education, and the creation of information conduits flowing from the education community back to the scientists, technologists, and support organizations creating STEM education materials.

Putting It All Together

NSDL outcomes have been accomplished by combining technical infrastructure with an organization that enables community participation, while building an effective mix of cutting edge and traditional dissemination methods. This combination has provided a framework to effectively deliver digital resources in support of educators, whether it is professional development, STEM knowledge and skills, classroom materials, or interactions with scientists and researchers. It has enabled a wide range of outcomes, including the following.

Visual Organization of Concepts, Standards and Resources

NSDL Science Literacy Maps⁵ are a significant advancement in contextualizing STEM knowledge across concepts and grade levels, and an excellent demonstration of NSDL's ability to broker stakeholder relationships to catalyze innovation. Science Literacy Maps utilize the American Association for the Advancement of Science (AAAS) Project 2061's *Atlas of Science Literacy*,⁶ which provides an organizing framework for modeling the connections between learning

goals across grade bands. In collaboration with AAAS and the University of Colorado at Boulder, NSDL has created a fully interactive online version of the Atlas and linked the key concept benchmarks within the maps to NSDL resources that support teaching these concepts in the classroom. This innovative service provides a visual representation of science concepts that supports students and educators in making connections between key ideas, and between scientific concepts and real-world applications. It also offers educators a way to align their curriculum development to state and national standards recommendations. Early research indicates that using Science Literacy Maps to discover teaching resources offers greater cognitive value than traditional keyword searching methods, and that the knowledge structure of the maps serves to reinforce conceptual frameworks while users are searching for materials.

Collaboration between Students, Teachers, and Researchers

An example of both the participatory and contextual advantages of the NSDL Data Repository (NDR) is Expert Voices,⁷ a blogging technology supporting online conversations among scientists, teachers, students, and others. These conversations represent a forum for scientific discussion tailored to the needs of education. The information surrounding STEM topics under discussion in the blog is related to NSDL resources, and the combined information is contributed to the NDR. Expert Voices can be used for topic-based discussions with links to related resources; as a way for resources to be reviewed and annotated; as a method of discovery for resources and news; as a mechanism to record and disseminate research results among collaborators; or as a question-and-answer forum.

K-12 Teacher Professional Development

An important partner in NSDL's professional development efforts is the National Science Teachers' Association. NSDL is bringing scientific experts from across Pathways and other projects to a monthly series of online workshops offered under the umbrella of NSTA's Web Seminars program.⁸ Through this partnership, NSTA benefits from NSDL's coordination of researchers in diverse discipline areas, as well as pedagogy and technology experts who model the effective use of digital materials in teaching scientific content. NSTA's other Web Seminar partners are federal agencies including NASA, NOAA, and the FDA. NSDL is representing NSF in this high-impact program, and the NSF-funded investigators who participate as presenters in the seminars benefit from the dissemination opportunity afforded by NSTA's reach to more than a quarter million science education professionals.

Multiplying Educational Impact

One of the most successful areas of collaboration has been the series of NSDL Pathway Workshops. Via supplemental funding from the National Science Foundation, Pathways have been able to present a wide variety of workshops that offer diverse professional development models. These workshops bear rich potential for further strengthening the NSDL reach through additional cross-collaborative workshops among multiple Pathways, and their partners, as well as 2nd tier outreach and dissemination by workshop participants. This year's workshops included:

MatDL:⁹ The workshop provided an opportunity for collaboration between NSF-funded programs and integration of research with education via NSDL and MatDL. Participants included NSF Materials Research Science and Engineering Centers (MRSECs) directors and staffs, NSF program officers (Division of Materials Research and Division of Undergraduate Education). Subsequent meetings on collaborative opportunities between MatDL and MRSECs at Cornell, MIT, Northwestern, and Princeton have taken place. MatDL has successfully encouraged and trained 25 Research Experiences for Undergraduates (REU) students at these MRSECs in the use of MatDL's Soft Matter Wiki to support their research and communicate their research results.

Math Gateway:¹⁰ This two-day teacher/faculty training workshop in digital library use and specifically NSDL, Math Gateway, and MathDL engaged 24 college and university math faculty, some who do K12 teacher outreach. Participants have since presented eight local presentations or workshops at regional or area conferences or meetings.

BioSciEdNet (BEN):¹¹ This workshop focused on promoting inquiry-based learning in higher education, and grassroots outreach for the BEN collection and NSDL. Participants included 21 biological sciences faculty members. Faculty have created learning materials, contributed these to the BEN collection, and devised outreach plans for dissemination of their materials including 2nd tier outreach via presentations/workshops to colleagues.

AMSER:¹² At the Innovations 2007 conference, AMSER presented a three-hour training workshop on AMSER and NSDL to 28 faculty and staff who work in educational settings. This effort led to 2nd tier outreach by participants to their colleagues either on their own campuses or other settings, using AMSER training materials, presentations, and evaluation materials.

CSERD:¹³ This two-day workshop for K-12 teachers and program directors introduced participants to digital libraries, and the resources of CSERD, NSDL, and other Pathways including Math Gateway, BEN, ChemED DL, and the Engineering Pathway. It engaged 22 educators and/or Student Science Enrichment Program (SSEP) Directors or staff. These participants have requested additional workshops.

Engineering Pathway:¹⁴ This combined online and in-person workshop was created for educators and Pathway Associate Editors, in a conference workshop setting. It supported the exploration of digital library resources and services. Participants included 10 educators online and 12 on-site.

comPADRE:¹⁵ A three and half day workshop for selected physics educators was held to help them utilize the physics modeling curriculum of the American Modeling Teachers Association and explore ways to develop and deliver their content via the web. Nine physics modeling teachers participated. They received orientation and training in the use of a wiki as a way to organize and deliver curricular content, and explored strategies for further developing content delivery via web-based means.

Teachers' Domain:¹⁶ WGBH held a Summer Science Forum for public television representatives and educators to provide an introduction to Teachers' Domain and NSDL services. Representatives from 13 PBS stations worked with local educational partners whom they invited (district or school administrators, teachers, education specialists). This forum provided the potential for expanding partnership efforts and for featuring NSDL on public television stations.

Disseminating Research

Reaching beyond educational and professional organizations, NSDL has established agreements with 20 scholarly publishers (including American Mathematical Society, Blackwell Publishing, Houghton Mifflin Company, Pearson Education, and Oxford University Press) to provide metadata for, and access to high quality published content. By providing technical assistance in adopting NSDL standards, publisher metadata has been ingested and made freely available through NSDL.

NSDL has also begun a program that will make original research easily available for teaching in an array of institutional settings beyond well-endowed research universities by expanding metadata-sharing arrangements with a group of scholarly publishers and aggregators. Two models presently under development,

"Timely Teaching" and "Classic Articles in Context," will incorporate current and landmark full-text articles into online modules within a larger educational digital library. Modules will be curated and edited by subject experts and presented through interactive collaborative spaces and disciplinary sections of the Library network.

Combining Traditional and Cutting Edge Dissemination

Publishers are also interested in ways to combine traditional publications such as textbooks with online and cutting edge technologies. Macmillan/McGraw-Hill is referencing NSDL in their K-6 science textbooks to connect teachers to NSDL-described materials that support teacher content learning at the point of need—a service that is of particular value to the large percentage of elementary educators who lack sufficient previous coursework in the sciences.

In addition to the traditional outreach methods that NSDL is facilitating on behalf of its broad network of partners, the library also capitalizes upon its technical expertise to help STEM education stakeholders expand their reach through new media tools often described as “Web 2.0”. Through social networking platforms including NSDL’s Expert Voices service, dissemination through RSS feeds, the provision of wikis, and lightweight flexible tools such as the NSDL Toolbar which plugs in to web browsers to improve resource discoverability, NSDL is prototyping new means for educators to interact with content, with scientific professionals, and with each other; and helping to define a new generation of best practices for educational outreach.

Engaging Established STEM Stakeholders

Through expanded outreach efforts, large educational systems such as the Southern Regional Education Board (SREB)¹⁷ are beginning to partner with NSDL as a source of quality K-20 learning and teaching materials, information about best practices, and teacher/faculty professional development. Administrators and classroom practitioners accustomed to seeking recommendations from SREB are now learning about NSDL as a valuable asset to their work and in turn SREB is enhancing its service to its 16-state constituency.

Closing the Feedback Loop

To gain feedback, Project Tomorrow (formerly Net Day)¹⁸ is contributing its expertise in surveying teachers and students about their real-world uses of technology to help NSDL understand how the library is being deployed in classrooms across the country—information which the library will share back out

to the broader STEM education community to aid understanding of real-world classroom needs and expectations.

On the dissemination side, NSDL is offering its outreach infrastructure, as well as digital library building tools and services, to an emerging partnership with the NSF Research Centers Educators Network (NRCEN) which aims to leverage opportunities and share best practices among the principal investigators and education /public outreach (EPO) professionals working in more than 213 NSF-funded research centers. NSDL's potential to facilitate broader impacts of NSF-funded research is also being realized for programs across NSF's Education and Human Resources directorate that have begun to include recommendations for disseminating research results through NSDL as part of program solicitations. These programs currently include the Nanotechnology Undergraduate Education (NUE) in Engineering and Course, Curriculum, and Laboratory Improvements (CCLI) programs.

Leveling the Playing Field

Beyond providing basic library services such as search, sophisticated technologies like Fedora help situate learners and educators in a broader context, and enable innovative services like Expert Voices and Science Literacy Maps. With such services, NSDL helps level the playing field by providing means for novice users to engage more deeply in STEM content. Other forms of access include using virtual labs such as Carnegie Mellon's ChemCollective Virtual Lab;¹⁹ finding well-vetted materials that can be combined and reused in new ways using tools such as Instructional Architect;²⁰ interactions with scientists and experts through Expert Voices; or joining communities through NSDL Wikis, a MediaWiki implementation in support of collaborative activities such as the cross-community redesign of physics modeling curriculum facilitated through NSDL's comPADRE physics pathway and the American Modeling Teachers Association.

Growing the Library through Pathways Development

In response to specific educator needs, Pathways are engaged in active collection building efforts, integrating both content and context for STEM resources, and refining infrastructure functionality and services. Examples of new collection efforts include supporting effective student use of data sets (ChemEd DLib);²¹ providing introductory undergraduate physics and relativity curriculum (comPADRE); and organizing community college topics and courses (AMSER).

In K-12 developing collections, Middle School Portal²² publishes both Quick Takes—one page publications highlighting three to four exemplary resources for 'just-in-time' teacher help—and Explore in Depth publications that feature

groupings of 20 resources in selected math and science topics, including reviews of the needed content knowledge and related educational standards. Teachers' Domain has expanded its Life and Physical Sciences Collection, is adding indigenous perspectives to selected resources, and has created an open access collection that permits use and reuse of resources.

Building Standards and Best Practices

From the beginning, policies, standards and best practices have been developed and adopted within the NSDL community and some have been adopted by the larger digital library community. These include standards and best practices for supplying and using NSDL metadata, ensuring user privacy, and improving cataloging practices. In addition, Pathways are organizing efforts within their own communities. In the past year, AMSER worked on developing controlled vocabularies on key concepts in applied math and science. ChemEd DLib is developing taxonomies for general chemistry, organic chemistry, physical chemistry, and video collections.

Supporting Formal and Informal Learning

In addition to providing access to lesson plans, course modules, materials to supplement text books, and standards-aligned tools that support formal classroom learning; NSDL also serves the informal education community of museums, science centers, public broadcasters, popular media, afterschool programs, community centers, and others. Informal education partners including the Exploratorium, WGBH Public Television, the Education Development Center, and the American Museum of Natural History are contributing a range of innovative learning resources to the library that are equally valuable inside and outside the classroom, and the broad range of NSDL tools and services support informal programming for students, teachers, and the general public in diverse settings. Other initiatives are targeted more specifically at the needs of informal education professionals, such as NSDL's participation in the Volunteers TryScience (VolTS) project funded through the Institute for Museum and Library Services (IMLS), and led by the New York Hall of Science, in which Expert Voices will facilitate the sharing of best practices for working with scientists as science center volunteers. As another example, an Exploratorium-led collaborative is using NSDL to support afterschool educators with science learning resources designed to meet their unique needs.

Summary

In NSDL's experience, success in meeting NSB goals will occur by building the capacity, both technical and organizational, to tap the knowledge and ambition of the broad range of STEM education stakeholders. Success in leveraging distributed partners and disparate communities requires coordination and facilitation of activities already taking place within these networks. In reality, these groups already have their hands full trying to meet their own specific goals and objectives. NSDL has learned that good coordination requires stepping back and looking for the patterns of activities that can be adopted and scaled for meeting larger goals and implementing the infrastructure, organizational processes, and best practices to help partners participate while meeting their own specific goals.

Coordination tasks are time intensive and dissemination efforts can be difficult in an Internet world that routinely creates information overload. But the action plan is clear in the end goals, and the collective effort will be best served by coordinating efforts based on meeting stakeholders where they are working today.

NSF has built a powerful and effective cognitive tool in NSDL, but what may be most effective is the growing NSDL network. That set of connections has the capacity for educational transformation based on the realities of educational challenge and the compelling necessity for educational success.

Endnotes

- ¹ National Science Board; National Action Plan for Science, Technology, Engineering, and Mathematics Education: http://nsf.gov/nsb/edu_com/report.jsp
- ² National Science Digital Library: <http://nsdl.org>
- ³ Flexible Extensible Digital Object and Repository Architecture (FEDORA): <http://www.fedora-commons.org>
- ⁴ NSDL Pathways partners: <http://nsdl.org/about/?pager=pathways>
- ⁵ NSDL Science Literacy Maps: <http://strandmaps.nsdl.org>
- ⁶ Project 2061 Atlas of Science Literacy: <http://www.project2061.org/publications/atlas/default.htm>
- ⁷ Expert Voices: <http://expertvoices.nsdl.org>
- ⁸ NSTA Web Seminars Program: http://learningcenter.nsta.org/products/symposia_seminars/NSDL/webseminar.aspx
- ⁹ MatDL, NSDL's materials science Pathway: <http://matdl.org>
MatDL's Workshop Report: <http://www.nsf.gov/mps/dmr/reports.jsp>
- ¹⁰ Math Gateway, NSDL's undergraduate mathematics Pathway: <http://mathgateway.maa.org>
- ¹¹ BioSciEdNet (BEN), NSDL's biological sciences Pathway: <http://biosciednet.org>
The BEN Scholars Program: <http://www.biosciednet.org/portal/about/benScholars.php>
- ¹² Applied Math and Science Education Repository (AMSER), NSDL's community and technical colleges Pathway: <http://amser.org>
- ¹³ Computational Science Education Reference Desk (CSERD), NSDL's computational science Pathway: <http://www.shodor.org/refdesk>
- ¹⁴ K-Gray Engineering Pathway: <http://www.engineeringpathway.org>
- ¹⁵ comPADRE, NSDL's physics and astronomy Pathway: <http://compadre.org>

- ¹⁶ Teachers' Domain, NSDL's K-12 multimedia Pathway:
<http://www.teachersdomain.org>
- ¹⁷ The Southern Regional Education Board: <http://www.sreb.org>
- ¹⁸ Project Tomorrow: <http://www.tomorrow.org>
- ¹⁹ Chem Collective Virtual Lab: <http://iry.chem.cmu.edu/vlab/vlab.php>
- ²⁰ Instructional Architect: <http://ia.usu.edu>
- ²¹ ChemEd DL, NSDL's chemistry Pathway:
<http://www.ice.divched.org/JCEDLib/index.html>
- ²² Middle School Portal, NSDL's middle grades Pathway: <http://msteacher.org>