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**The NSF National Science,
Mathematics, Engineering, and
Technology Education Digital Library
(NSDL) Program**

A Progress Report

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(All views expressed in this article are solely those of the author and do not represent an official NSF policy statement.)

To stimulate and sustain continual improvements in the quality of science, mathematics, engineering, and technology (SMET) education, the National Science Foundation (NSF) has launched the National Science, Mathematics, Engineering, and Technology Education Digital Library (NSDL) program. The resulting digital library is intended to serve the needs of learners belonging to a broad user audience -- K to 12, undergraduate, graduate, and life-long learning - - in both formal and informal settings. Envisioned as the premier portal to current and future high-quality SMET educational content and services, this virtual facility will enable seamless access to a rich array of interactive learning materials and resources, distinguished by the depth and breadth of the subject matter addressed, and valued for its authority and reliability.

Initial development of the NSDL program began in late 1995 with an internal concept paper for the NSF Division of Undergraduate Education (DUE). Mogk and Zia examined the opportunities and challenges in evaluation and dissemination that would be implied by a national digital library for science education [7]. Subsequently, the idea was explored and developed further through a series of workshops and planning meetings over the next several years [1-6]. Wattenberg drew together some of these themes into an early vision for the organization and architecture of the digital library [8]. Beginning in 1998, two rounds of prototype projects were supported through the Special Emphasis: Planning Testbeds and

Applications for Undergraduate Education program conducted under the auspices of the multi-agency Digital Libraries Initiative - Phase 2 (DLI-2) program (<http://www.dli2.nsf.gov>) More information about these projects may be found at <http://www.ehr.nsf.gov/ehr/du/programs/nsdl/projects.asp>. While most of these projects focused on what is most easily recognized as collection development, others began to explore organizational and managerial functions of a digital library.

The NSDL program held its first formal funding cycle during fiscal year 2000 with a proposal deadline in mid-April 2000. Proposals were accepted in four tracks: **Core Integration System**, **Collections**, **Services**, and **Targeted Research**. For more information, see the program site at <http://www.ehr.nsf.gov/ehr/du/programs/nsdl/>. Nearly 90 proposals were received in response to this solicitation with approximately \$59M in total funding requested. Twenty-nine projects have recently been awarded support with a cumulative budget of approximately \$13.5M. These include six pilot projects in the **Core Integration** track, thirteen projects in the **Collections** track, nine projects in the Services track, and one project in the **Targeted Research** track. It is worth noting that two NSF directorates, the Directorate for Geosciences (GEO) and the Directorate for Mathematical and Physical Sciences (MPS) are both providing significant co-funding on several projects, illustrating the NSDL program's facilitation of the integration of research and education that is an important strategic objective of NSF. In this same vein, the NSF Division of Undergraduate Education is co-funding two DLI-2 projects under the new joint NSF/DFG (Deutsche Forschungsgeheimschaft) International Digital Library Initiative that have significant educational collection development aspects. One project, IIS-0085960, is developing an open digital library focusing on the history of mechanics, and the second project, IIS-0085853, is creating a digital library of historical mathematical monographs. Both projects will enable creative historical approaches to the teaching and learning of science. (IIS is the NSF Division of Information and Intelligent Systems, which houses the DLI-2 program.)

Following is a list of the awards displaying the title, the grantee institution, the name of the Principal Investigator (PI), and the official NSF award number. A condensed description of the project is also included. Full abstracts are available from the Awards Section at the NSDL program site <http://www.ehr.nsf.gov/ehr/du/programs/nsdl/>. (Projects with shared titles are formal collaborations and are grouped together.) The projects are displayed by track and are listed alphabetically by name of the PI. In addition, eleven of these projects have explicit reference to applications to K-12 education (indicated with a * below). Six others clearly have potential for application to the K-12 arena (indicated with a ** below).

The NSDL program will have another funding cycle in fiscal year 2001 with the next program solicitation expected to be available in the late fall of 2000, and an anticipated deadline for proposals in mid-April 2001.

Core Integration System Track - projects are expected to focus on the coordination and management of the library's core collections and services and to develop the library's central portal.

Developing a Core Integration System for a National Science, Mathematics, Engineering, and

Technology Education Digital Library at WWW.SMETE.ORG. Institution: University of California at Berkeley. PI: Alice Agogino. DUE-0085878*. This demonstration project is providing horizontal and vertical integration of a suite of collections and services for a comprehensive national digital library for SMET education. Towards this goal the project has formed an alliance of twenty partner organizations, including several which have strong ties to the K-12 SMET community: the Eisenhower National Clearinghouse, SRI's TAPPED-IN online professional development community (over 8,000 teachers, teacher educators, and educational researchers), and Texas Instruments -- long an active supporter of teacher professional development workshops and activities centered around the use of hand-held calculators.

The NSDL Central System. Institution: Cornell University - Endowed. PI: William Arms. DUE-0085753. The *NSDL Central System* project is building a prototype of the central core of the national digital library for SMET education envisioned by the NSDL program. Technologies and expertise in four areas are being provided: technical infrastructure, metadata standards, services and organization, and digital library research.

The National Biology Digital Library. Institution: University of Missouri - Columbia. PI: Su-Shing Chen. DUE-0085735. This project is developing and studying key requirements of user services, management procedures, and technical standards for a core integration system, using as a content test bed the rich plant contents of the Missouri Botanical Garden and NSF Plant Genome projects at the University of Illinois and the University of Missouri - Columbia.

Core Integration Services for a Federated NSDL. Institution: University Center for Atmospheric Research. PI: David Fulker. DUE-0086100*. This project is developing aspects of both a technical infrastructure for user services and a social foundation for community governance of the operation of a national digital library for SMET education. It builds on current efforts that focus on a digital library for earth systems education that have been jointly sponsored by DUE and GEO. Included among the collaborators is the "Windows to the Universe" web project which is a K-12 interdisciplinary materials development and dissemination site linking the Earth and space sciences with related arts and humanities content.

TeacherLIB - Digital Community and Collections for Science and Mathematics Teacher Education. Institution: Eastern Michigan University. PI: Ellen Hoffman. DUE-0085866*. The goal of this project is to develop an information infrastructure that joins two threads -- i) high quality, focused, and well-maintained collections and ii) an intelligent, interactive, and community-based user interface -- to assist teachers in developing powerful science and mathematics learning materials for the secondary classroom. While providing a digital library context for educators, TeacherLIB is itself a learning environment that showcases the Internet's most powerful features for knowledge acquisition.

Columbia Pubscape - A Core Integration System for a National Science Digital Library Publishing Center. Institution: Columbia University. PI: Kate Wittenberg. DUE-0085870. This project has assembled a diverse team representing a university press, academic libraries, and an academic information systems computing center, to develop models for rights management,

sustainability, business partnerships, and archiving systems as part of the functionality of a core integration system for a national digital library supporting SMET education.

Collections Track - projects are expected to aggregate and manage a subset of the library's content within a coherent theme or specialty.

Biology Education Online - An Interactive Electronic Journal. Institution: National Association of Biology Teachers. PI: Wayne Carley. DUE-0085874*. This project is creating a peer-reviewed on-line journal on the subject of teaching and learning biology, and a collection of reviewed digital resources aimed at biology educators at many different levels. Materials and other resources in the collection exemplify the multimedia capabilities characteristic of digital media and are consistent with the K-12 National Science Education Standards and the AAAS Benchmarks for Science Literacy.

A Digital Multimedia Library for Health Sciences Education. Institution: University of Utah. PI: Sharon Dennis. DUE-0085660. This project is building a collection of multimedia resources around the general theme of the health sciences and developing associated services to enable users to find, upload, catalog, retrieve, and exchange digital media. This work leverages an emerging NSDL program collaboration with the National Library of Medicine on common digital library issues.

Bioscience Education Net. Institution: AAAS. PI: Yolanda George. DUE-0085840**. The objectives of this project are to develop a portal site to a collection of resources (tools and products) for the teaching and learning of biology by students at the undergraduate level with diverse interests and career aspirations (i.e., science majors, non-science majors, and prospective K-12 teachers). The materials are being collected and maintained by respected professional societies representing a broad spectrum of biological sciences from the molecular level to macroscopic population levels.

Collaborative Project - To Gather, Document, Filter and Assess the Broad and Deep Collection of the Digital Library for Earth Systems Education. Institutions: Columbia University, American Geological Society, Foothills Community College, and Dartmouth College. PIs: Kim Kastens (lead), Sharon Tahirkheli, Chris DiLeonardo, and Barbara DeFelice, respectively. DUE-0085827*, 0085787, 0085831, 0085839. This project is building a representative collection initially containing resources suitable for teaching Earth system science at the secondary school and undergraduate levels. These resources will include laboratories, support for full courses, images of real phenomena, conceptual images, scientific papers, lesson plans, assessment tools, pedagogy tutorials, professional opportunities, animations of observed data, animations of models or simulations, virtual field trips, problem sets, large datasets, tools to analyze large datasets, student portfolios, geoscience theme pages or portal sites, history of geoscience, and lecture materials.

Atmospheric Visualization Collection. Institution: Argonne National Laboratory. PI: Chris Klaus. DUE-0086225*. The *Atmospheric Visualization Collection* project is aggregating visualizations of atmospheric data from the Atmospheric Radiation Measurement program's Southern Great Plains site which is the world's largest group of remote sensing atmospheric

instruments. The creation of a model user and provider community of students and teachers is being enabled by this project, which will support the collection of visualization codes, implementations of those codes, and review of the visualizations for educational appropriateness.

MATHDL - A Library of Online Learning Materials in Mathematics and Its Applications.

Institution: Mathematical Association of America. PI: Lang Moore. DUE-0085861**. This project is developing a collection of independently reviewed learning materials for learning and teaching undergraduate mathematical sciences. While the primary focus of the proposal is at the undergraduate level, significant portions of the materials will be useful to secondary mathematics educators and students as well.

A Digital Library Network for Engineering and Technology. Institution: Virginia Polytechnic Institute and State University. PI: Saifur Rahman. DUE-0085849. This project seeks to facilitate the life-long learning of engineering faculty, practicing engineers, and technical professionals through the creation of a digital library network for engineering and technology (DLNET). Functionality under development includes content hosting capability, creation of standardized templates for posting new content, and a process for electronic review and validation of materials.

National Digital Library for Undergraduate Mathematics, Science, and Technology Teacher Preparation and Professional Development. Institution: Ohio State University. PI: Kim Roempler. DUE-0085823*. This project seeks to build a Virtual Teacher Resource Center to provide seamless access to high quality learning materials for pre-service and in-service teachers. The effort will be aided by the involvement of the Eisenhower National Clearinghouse that has developed expertise in implementing a range of digital- and human-based services for library users.

Collection and Distribution of Geoscience (Solid Earth) Data Sets for the National Science Digital Library. Institution: Cornell University. PI: Dogan Seber. DUE-0085718*. Two goals define the focus of this project: i) collecting, organizing, and maintaining geoscience data sets for use in a national digital library for SMET education, and ii) developing advanced user tools to manipulate, map, model, visualize, and analyze the collected data sets. The proposed activities include development of a series of learning modules that college and secondary school teachers can integrate into pre-existing earth science curricula.

The Alsos Digital Library. Institution: Washington and Lee University. PI: Frank Settle. DUE-0085657. This Web-based collection of references to resources offers a broad, balanced perspective of topics relating to the origins, functions, and legacies of the Manhattan Project. The central task of this project is to integrate these references into a structured architecture that allows users to examine this important period of history from many scientific, engineering, technological, and social perspectives.

Services Track - projects are expected to develop services that support users, collection providers, and the Core Integration System and which enhance the impact, efficiency, and

value of the library.

Improving Knowledge Transfer: Prioritizing Content Creation in Digital Libraries Using Competitive Intelligence Systems. Drexel University. PI: Michael Atwood. DUE-0085713**. This project is using high-end multi-agent collaborative competitive intelligence systems to identify and acquire relevant content for digital libraries. By analyzing experts' information seeking and problem solving strategies and translating these into tools to guide novice learners, the project intends to develop a service that complements human-centered knowledge discovery and transfer. The project begins with the awareness that there are different needs of learners at different levels, with different learning styles, and it is anticipated that the project's results will be applicable to all educational levels.

Peer Review of Digital Learning Materials: A Critical Service for Digital Libraries. Institution: California State University. PI: Gerry Hanley. DUE-0085913**. This project, from the Multimedia Educational Resources for Learning and Online Teaching (MERLOT) initiative, is developing tools and processes for quality assurance of digital learning materials. Although the project is initially focusing on higher education, the project's results (i.e., a peer review mechanism with discipline-specific flavors) would likely be extendable to all user levels of the digital library.

Implementing an Electronic Peer-Reviewed Journal of Earth System Science Education Resources (JESSE) - A Pathfinder for SMETE Resource Peer Review. Institution: Universities Space Research Association. PI: Don Johnson. DUE-0085793**. This project is designing, implementing, and evaluating a novel mechanism for electronic peer review, using a new e-journal as a test bed for the process. The initial emphasis is on the publication of resources to be used at the university level, but it is anticipated that this emphasis will extend to lower grade levels and also to informal education as submissions and user needs demand.

Breaking the Metadata Generation Bottleneck. Institutions: Syracuse University and solutions.com. PIs: Liz Liddy (lead) and Woojin Paik, respectively. DUE-0085837* and 0085838. This project is developing a system for automating the classification and assignment of metadata through use of natural language processing and machine learning. The system will be initially applied to collections taken from the Eisenhower National Clearinghouse, with a focus that includes K-12 resources. A particularly relevant component is a user study involving teachers, parents, and students.

The Instructional Architect: A System for Discovering, Recommending, and Combining Learning Objects. Utah State University. PI: Mimi Recker. DUE-0085855*. This project is providing instructional support by automated recommendation of learning objects to enhance a national library of interactive Web-based mathematics learning manipulatives, with a primary focus on K-12 education (students, teachers, pre-service teachers). The effort is housed in the Instructional Technology Department in the College of Education. Pilot testing is occurring with pre-service teachers and inservice teachers are providing review of prototypes and models.

Threading Information Pathways through NSDL Video. Institution: Carnegie Mellon

University. PI: Howard Wactlar. DUE-0085834**. The focus of this project is on the provision of management tools (indexing, metadata, annotation by educational users, use trails, etc.) for all NSDL video content, including K-12 components. The PI and team see very promising opportunities for utilizing the project's results at *all* levels of education.

Collaborative Research: A Component Repository and Environment for Assembly of Teaching Environments (CREATE). Institutions: Carnegie Mellon University and Brown University. PIs: David Yaron (lead) and Andries van Dam, respectively. DUE-0085862 and DUE-0085826. The *CREATE* project seeks to provide two related services to the national digital library for SMET education. The first service -- aimed at developers -- supports collaborative creation of a broad spectrum of learning objects for use in learning environments. The second service -- aimed at teachers -- provides an assembly environment for flexible creation of curriculum materials that utilize the learning objects.

Targeted Research Track - projects are expected to explore specific topics that have immediate applicability to one of the other three tracks.

Metadocuments as Communicative Artifact to Enable Use of a Research Digital Library in Undergraduate SMET Education. Institution: Texas Engineering Experiment Station. PI: Rick Furuta. DUE-0085798*. This project is investigating the application of a knowledge organizational mechanism termed a "path" or "guided tour" to the navigation and contextualization of Web-based learning material in the area of floristics and entomological models. The initial applications of "paths" have been at the K-12 level and these are being enhanced, as well as extended to the undergraduate level.

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