

Project Summary - Repositioning NSDL for the Next Generation of Digital Learning

The proposed scope of work is a concentrated set of activities intended to expedite the systems innovations and renovations necessary for the National Science Digital Library (NSDL) to remain responsive to changing opportunities for STEM education. This proposal represents a strategy to leverage the successes and lessons of several recent pilot projects, bring them to scale, iterate toward additional improvements, and integrate new capacities into NSDL's baseline value propositions. Goals and activities for the proposed work focus on **Transitioning NSDL's Technical Infrastructure, Transitioning Library Collections, and Redefining NSDL's Network Effects**—all toward evolving the library to an NSDL 3.0 model that is a responsive tool for the next generation of digital learning. The project will be led by teams currently involved in the operations of the NSDL Resource Center and Technical Network Services. Investigators will also partner with a cadre of eight previously funded NSDL Pathways projects as an advance team for the NSDL community to co-create new processes, policies, shared practices, and collaborative resource collections designed to create new opportunities for educational impact and additional points of sustainability leverage—for the library and its partners.

Intellectual Merit

Perennial challenges for cyberlearning projects include integrating digital learning resources meaningfully into the workflows of users, and measuring the impact of those resources on educational practice. The proposed work addresses these issues with non-traditional approaches that leverage the collective expertise of NSF's NSDL grantees community, along with networked systems of education practitioners, and their online collaborative workspaces. The project will yield new NSDL collections for Learning Application Readiness and Common Core Standards Alignment that will be openly shared via the STEM Exchange, a growing consortium of online teacher communities, state education portals, and open educational resource (OER) providers. Through the STEM Exchange, aggregated and anonymized data streams about resources usage (defined by NSDL as paradata) will be returned to NSDL as teachers interact with digital content in their online collaborative workflows. Paradata will be shared as open data reassociated with resources as they are continually shared across the network to facilitate educators' capacity to embed resources in instructional practice. A major initial activity for the project will be relocating NSDL's technical infrastructure from Cornell University to UCAR. This will prepare the library to evolve its potential as innovation architecture that supports the multitude of content, authorship, and resource sharing environments that now proliferate the online lives of educators and students.

Broader Impacts

The proposed work will significantly enhance the utility and discoverability of the digital resources funded by NSF through ten years of the NSDL program. Resources will be aligned to new Common Core Standards, and mapped to an emerging set of Learning Application Readiness (LAR) criteria that NSDL will publish as an open framework. These processes will increase the potential for NSDL collections to be adopted into a wider range of instructional paradigms and more broadly shared through teacher peer-to-peer networks. Project activities, including the STEM Exchange, will accelerate the diffusion of digital resources through collaborative online teacher communities; capture in situ data about how users share, personalize, and recontextualize resources for their own instructional practices; and make this user activity data broadly visible to other users as an indicator of resource utility. Through involvement in the Learning Registry, NSDL is contributing to a multi-agency federal project designed to make learning resources produced by the federal government more accessible. The initiative is combining traditional metadata with paradata generated by digital systems close to the end-users to create a richer pool of data for improving recommendation and relevancy engines, and to enhance research into teacher practices and effectiveness. The transition of NSDL technical infrastructure to UCAR and commercial cloud-based service providers will give the library a robust, flexible, high-availability operational platform and reduce the costs associated with library operations. These factors will ultimately have a positive impact for the community, as NSDL will be positioned for a more sustainable and flexible operational presence going forward.

PROJECT DESCRIPTION

1.0 Repositioning NSDL for the Next Generation of Digital Learning

A decade ago the digital library world assumed that access to what had often been scarce—resources—would be transformational for STEM education, almost in and of itself. We assumed that NSDL.org should, and would, become a single portal for STEM resources and that we could expect large numbers of users (NSDL 2001). NSDL was also asked to serve all users (“K to Grey” as we liked to say) and include both research and educational materials. The former Core Integration group was sometimes criticized by the larger NSDL community for putting too much emphasis on the technology and not enough on the content of the library, of slighting the educational mission of NSDL. There were, in that central group, internecine wars over metadata, though these were no doubt proxy struggles over whether we should base our sense of NSDL in old, valuable and proven ideas or look forward to a world of information and communication only beginning to emerge, but full of so much promise and intellectual energy. As usual in theological controversy, positions excluded each other and we lost a lot of valuable time in our development.

Or did we? There really is a time to things, and when a powerful new phenomenon emerges—like the Web, and all it makes possible—the range of its possibilities and the implications of those possibilities must be lived out. Value becomes defined by use and the shared experience of the network of people and institutions that pick up the tool. Those are moments of marked messiness, but critical to creative human activity. They begin to play with it and learn from it, discover its power in ways that are seldom that obvious in the beginning. As a player in that new arena, NSDL and its ever-growing and diverse network gradually created a significant role in the digital world (NSDL 2007; NSF 2008; Van Gundy 2010b). Some of the instances that moved us toward that significance:

Pathways and the NSDL Network - After a period of what could seem random NSDL grants, NSF focused major resources on the Pathways, themselves networks of networks assembled as NSDL portals on behalf of disciplines or audiences (NSDL 2005 - 2011; NSF 2010). That gave NSDL a coherent and continuing group of partners, and a set of evolving and open relationships and resources coordinated and brokered, first by Core Integration and then by the Resource Center and Technical Network Services. Relationships grew among and between them and new partners are constantly added. The result has been continuous learning and adaptation as each of the partners learned both from its immediate context, and relationships to others, then passed that learning on to the network. This network of interactive partners is, in fact, the platform of NSDL.

The Collection and Its Audiences - We looked at our user profile and saw that middle/high school and early undergraduate defined our primary audience. It clearly emerged that STEM education, and not disciplinary research resources, was our niche (Khoo 2006; Devaul 2010; Devaul and Clark 2010). Given the insights that usage data provided we also saw that quality in both metadata and content were the priority, not volume, as we thought in the beginning. In just the last two years we have gone through major deaccessioning, dramatically reducing the size of the collection, making search much more efficient and delivering fewer but more appropriate resources for instructional use. We are continuing that process with increasingly refined and demanding metadata and content standards. Curation and contextualization became watchwords as we understood that the educational impact of a resource was related to how easily and effectively it could be embedded in an educational context whether that was a classroom, or the curiosity of an independent learner. Resources must be well made for users and their needs. High quality metadata must make them usefully discoverable. The low bar we set at the beginning with NSDL Dublin Core got us high volume with scant metadata and that, we found, can be inimical to educational use and impact.

Real Data from Real Classrooms - Our partnership with Project Tomorrow gave us access to voluminous annual data from surveys - and focus groups in selected but diverse school districts,

about what was going on with students and teachers in the use of technology in the K-12 classroom. If our early focus had been on the creator of resources, we now saw before us the compelling realities of the classrooms that these materials were ostensibly created for. We saw a complex world in which students were routinely far ahead in the integration of technology into their daily lives and tasks. We saw a world where the ubiquity of the digital world and access to unlimited information and communication was creating a wonderful but challenging autonomous learner, whom the world of traditional learning and authority ignores at its peril (Evans 2011a; Evans 2011b). Most of all, we saw the need to integrate educational resource creation and a realistic sense of educational environments and their learners (NSF 2011).

Convergence - Our initial assumptions were from the world we knew a decade ago. Over ten years, the NSDL network has learned in ways that are kaleidoscopic—if a kaleidoscope were an open, not a closed universe—with all the bits, the variables, converging to create new insights. The most powerful convergence now is between the dynamically refined digital resource and rapidly evolving learners and learning environments. Our ability to observe and understand those robust interactions, and continuously recreate a resource and its relationship to increasingly adaptive and untethered habits of use, is the very center of our next decade of work. We have already begun this work with a series of pilot projects that relocate the center of NSDL’s value in our ability to leverage the kaleidoscope of information in the network—including the tacit knowledge of the educators and learners who use the library’s resources for their own immediate needs and highly localized circumstances. Next steps to this transitional NSDL are the basis of this proposal.

2.0 Goals and Activities

The National Science Digital Library entity—as distinct from the NSDL funding program within the National Science Foundation—is currently operated under cooperative agreements with NSF for a *Resource Center*, based at the University Corporation for Atmospheric Research (UCAR), and a *Technical Network Services* group led by Cornell University, with UCAR and University of Colorado. Both groups have been preparing for long-term sustainability of the library, in part, by piloting ideas that hold promise for helping NSDL and the communities it serves respond to changing trends in STEM education, educational policy, and learning technologies. These experimental approaches break with the traditional digital library construct, and yet are deeply rooted within it; potentially offering diversified options for funding continued operations and achieving educational impact.

Lightweight infrastructures with robust feedback mechanisms, and targeted context mapping are themes of recent work on which we propose to build the next generation of NSDL. Projects such as **Learning Application Readiness**, **Common Core Collections**, and the **Science Literacy Maps** recognize new realities of classroom instructional demands and work as supports for the formal structures of the K12 system and its related accountabilities. The **STEM Exchange** and **Learning Registry** initiatives operate within the more openly structured participatory web culture of user-created content, crowd-sourcing, and social networking; as well as ubiquitous, mobile, self-directed learning. Both approaches are highly relevant, and valuable for embedding NSDL resources, tools, and services in user communities of practice. By enabling resources to be discovered and contextualized directly in the workflows of practitioners, we can begin to observe patterns in datastreams generated by authentic online resource use.

This proposal represents an opportunity to leverage the successes and lessons of these recent pilots, bring them to scale, iterate toward additional improvements, and integrate new capacities into NSDL’s baseline value propositions. Goals and activities for proposed work focus on **Transitioning Technical Infrastructure**, **Transitioning Library Collections**, and **Redefining NSDL’s Network Effects**—all toward evolving the library to an NSDL 3.0 model [Figure 1] that is a responsive tool for the next generation of digital learning. The proposed scope of work is a concentrated set of activities intended to expedite the systems innovations and renovations necessary for NSDL to remain

relevant and responsive to changing opportunities for STEM education. At the same time, UCAR will continue baseline operations that keep the main corpus of library resources accessible through NSDL.org and other channels, continue to accession resources from new and existing providers, and continue to meet our responsibilities as a resource center for the NSDL projects' community.

Figure 1: Evolution of NSDL as a Cyberlearning Platform

	NSDL 1.0 (c. 2000-2005)	NSDL 2.0 (c. 2005-2011)	Transition (Current Proposal)	NSDL 3.0
Technical Infrastructure	<p>Metadata Repository</p> <p>Basic database with focus on metadata repository. Intended to handle highly structured metadata sharing between repositories.</p>	<p>Semantic Data</p> <p>“Resource centric” Fedora-based repository. Intended to encourage mapping relationships between resources.</p>	<p>Streamlining</p> <p>Streamlining operations by moving infrastructure from Cornell to UCAR and cloud computing services, with the goal of achieving economies of scale, lowering maintenance costs, and positioning for increased flexibility of future options.</p>	<p>Flexible Collaboration Infrastructure</p> <p>Open source code, tools, standards, metadata, and paradata as the basis of an agile and extensible structure that can respond to changing practices and technologies, allow for observation of user behaviors via automated data collection, and support NSDL’s future sustainability.</p>
Collections	<p>Aggregation</p> <p>Enterprise vision of digital libraries as mass aggregators and “one stop shops” focused on largely static reference materials and digitized text coming from other aggregators, academia, and commercial publishers.</p>	<p>Curation</p> <p>Shifting emphasis from quantity to quality and the importance of curation. NSDL initiates Pathways as curators for differentiated learning communities and begins to create contextualized collections. Metadata quality analysis leads to deaccessioning a significant part of the original library.</p>	<p>Contextualization</p> <p>Collections refinement driven by concepts of pedagogic utility over abstract quality definitions, and the demand-side of evolving user needs.</p> <p>Convergence of new contextualization models: Learning Application Readiness (LAR), association of resources to educational standards, and <i>paradata</i> as a construct for contextualization generated through the networked use of resources.</p>	<p>Responsiveness</p> <p>Creation and management of resources that are easy to discover, use, reuse, implement in local contexts, and metabolize in networked learning environments. Flexibility for open content to be used in digital textbooks, mobile devices, learning management systems, and state-level portals.</p> <p>Supporting expanding paradigms around the value of teacher and student-created content and teacher and student generated contextualization.</p>
Community Network	<p>Centralized Library</p> <p>The launch of NSDL served as a proof of concept for digital library research and as a unique convener of information technology researchers and scientists with an interest in education at all levels.</p>	<p>Distributed Hubs</p> <p>The centralized technical and community services offered through Core Integration created a lively, but distributed model with CI as a hub for Pathways and other projects, and Pathways as hubs for cross-community activities.</p> <p>Increased interconnections create a robust cyberlearning platform that is the community itself.</p>	<p>Networked Platform</p> <p>NSDL projects report high value for the collaboration ethos and opportunity brokering that has emerged from positioning NSDL at the nexus of digital content and education reform.</p> <p>Capitalizing upon that position by conjoining NSDL with online networks of educational practitioners through initiatives such as the STEM Exchange, Learning Registry, and Curriculum Customization Service.</p>	<p>Innovation Architecture</p> <p>NSDL as a substrate that engenders opportunities for spontaneous collaborations, multiscalar connections, high-volume data exchanges, and multidisciplinary tool/idea sharing that can nurture innovation.</p> <p>NSDL 3.0 will leverage this richness to promote the implementation of digital content and services as significant elements of educational reform that supports teachers as learners and students as constructors of knowledge.</p>

2.1 Community as Platform

NSDL's ability to innovate and achieve educational impact is dependant upon a diverse ecosystem of large and small entities whose interleaved efforts produce, consume, process, aggregate, reorganize, embellish, and tinker with digital content. As a result, the primary strategy for accomplishing the transitional objectives defined within this proposal is to leverage the strengths and capacities of core partners, and expand their level of engagement as co-producers and co-beneficiaries of NSDL 3.0 models and services.

- **NSDL Pathways:** A cadre of institutions previously funded as NSDL Pathways will partner with UCAR in achieving the goals of this project. Teams from the Applied Mathematics and Science Education Repository (**AMSER**) and **Middle School Portal** Pathways will serve critical roles in cataloging, contextualizing, and processing subsets of materials from other Pathways' collections (Bower and Almasy 2011; Lightle 2011). An additional six Pathways (**ChemEd DL**, Climate Literacy and Energy Awareness (**CLEAN**), **compADRE**, **Engineering Pathway**, Science and Math Informal Learning Educators (**SMILE**) Pathway, and **Teachers' Domain**) will serve as an advance team for other NSDL projects by collaborating to define new guidelines for sharing enhanced metadata and resource usage data across the network (Ledley, Niepold et al. 2011; Mason 2011; Moore and Holmes 2011; Porcello and Hsi 2011; Sicker 2011; Sullivan, Reitsma et al. 2011). These Pathways will pilot new approaches with appropriate subsets of their own collections.
- **National Stakeholders:** The proposed work will extend and reinforce relationships built through development of the STEM Exchange and Learning Registry projects with the White House Office of Science and Technology Policy (OSTP 2011), the Office of Educational Technology at the U.S. Department of Education (OET 2011) and the Advanced Distributed Learning Lab at the Department of Defense (ADL 2011). The non-profit, Achieve, will collaborate on proposed work to align NSDL resources with new Common Core and Next Generation Science standards (Achieve 2011a).
- **State Portals and Other Teacher Communities of Practice:** Partners from our pilot work on the STEM Exchange project will continue as collaborators including the Center for the Advancement of Digital Resources in Education (CADRE) at the Butte County Office of Education in California (CADRE 2011), the Learning Systems Institute at Florida State University (Lang 2011), and Intel Corporation (Intel 2011). The Southern Regional Education Board (SREB 2011) will help us connect their consortia of state virtual schools and learning object repositories to the STEM Exchange and Learning Registry networks, and we will continue similar conversations currently in process for state level portals in Maryland and Colorado, and the BetterLesson social network (BetterLesson 2011).

2.2 Transitioning the Technical Infrastructure

The future of NSDL as a viable learning tool requires a robust, stable, and sustainable infrastructure. In October 2008, NSDL Technical Network Services was formed to operate NSDL technical infrastructure on behalf of NSF and the NSDL community of grantees and users (Cornell University, UCAR, and University of Colorado). This includes tools and services for creation, curation, and discovery of collections of digital teaching and learning resources via NSDL.org and search APIs, along with support, training, and consultation on collection development and use of NSDL tools.

The current proposed work includes transitioning selected critical infrastructure related to core tools and services, currently housed at Cornell, to a combination of UCAR and commercial cloud services to ensure quality of performance and a 24/7 level of service. The transition plan will focus on minimizing maintenance costs and the overall software stack to a minimal set of essential services defined in this proposal and used by the NSDL community. These include tools and services that support collection development and curation, repository management, and consulting services for web-based applications that help teachers and learners to effectively use digital content (e.g. Strand Map Service, NSDL Science Literacy Maps, Common Core Math collection). UCAR will continue to provide training and support for the use of core NSDL tools and services (NSDL 2011a):

- **NSDL Collection System (NCS)** - the open source collection management system of NSDL. The NCS is a flexible XML-driven tool providing a full-featured metadata editor, collection workflow

processes, and a role-based permission system in support of distributed and collaborative collections management.

- **Digital Discovery System (DDS)** - an enterprise search server and XML repository system optimized to support rapid construction of audience-specific portals and applications; can be flexibly configured to search over any XML structure. The DDS is used to implement the NSDL Search API web service for the NSDL repository at nsdl.org.
- **JOAI** - an Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH) data provider and harvester tool enabling existing systems and databases to provide metadata via OAI-PMH and to harvest metadata to the file system. The tool enables NSDL partners to interoperate with the NSDL via the OAI protocol. Collections come into NSDL either by harvesting via OAI, or collection-management processes embedded in the NCS.
- **Strand Map Service (SMS)** - a web-service protocol supporting construction of interactive knowledge map interfaces based on learning goals articulated in the American Association for the Advancement of Science (AAAS) Benchmarks for Science Literacy.
- **Instrumentation** - UCAR will continue with pop-up surveys, analytics, and expand metrics collection through LAR processes. UCAR will also gather metrics from Pathways partners.
- **Resource Vitality Service** - a resource monitoring and reporting service that visits all resources in the NSDL repository on a regular basis and provides alerts and reports to NSDL collection providers regarding their resource availability.
- **Metadata Frameworks** - to support collection development, resource description, standards alignment, and annotation.

UCAR will provide primary support for NSDL collection curation services, including operating the collections infrastructure and managing collections processes, such as ingest and vitality services to ensure resources are available to users, and responding to user support queries through a request tracking system. NSDL will continue to support any collection development group who wishes to contribute to the library in accordance with NSDL policies, vision, and priorities; and will also provide services to the NSDL Accessioning Board (NAB), which has primary responsibility for approving accessioning and deaccessioning decisions for the NSDL collection. This includes consulting with collection developers and the NAB to ensure collections are in scope, resources meet NSDL quality guidelines, and metadata descriptions adhere to NSDL Learning Application Readiness (LAR) standards [p.6]. UCAR will continue to provide consultation and support for NSDL tools and services including metadata frameworks and vocabularies, use of OAI, the use of the NSDL Collection System (NCS) and NSDL Search API web service. UCAR will provide web development and metrics instrumentation and reporting services such as user surveys for both NSDL.org and API services on the use of collection and resources. Beyond the period of performance, long-term operations for repository services will be continued through the National Center for Atmospheric Research (NCAR) Library at UCAR. Supplementary Documentation includes 1) detail for infrastructure and curation processes: NSDL Transition and Collection Curation Plan, and 2) Data Management Plan.

2.3 Transitioning Library Collections

The relevancy and currency of NSDL's resource collections are critical to sustainability across the network. This proposal outlines a three-pronged approach to strengthen policies and processes around metadata, enhance the pedagogic utility of resources, and ready collections for the evolving ways that teachers want to find and use digital content. **Learning Application Readiness** will reinforce core metadata quality against criteria for educational utility. **Alignment of resources to educational standards** will address an urgent national need for quality resources correlated to the Common Core. The development of open **paradata** exchange with online communities of practice will unlock a flow of user activity data through which we can observe patterns of teachers' digital content habits and infer resource utility from the actions of the users themselves.

+ Learning Application Readiness

In 2009, NSDL undertook a significant effort to systemically review its collections and deaccession metadata records for materials lacking sufficient value for STEM teaching and learning based on

criteria that included content, scope, accessibility, functionality, metadata completeness, and other factors. The deaccessioning process yielded a more educationally useful collection and brought into focus a range of shortcomings in the metadata practices of NSDL's collections contributors. The *Learning Application Readiness* (LAR) initiative (Ginger and Goger 2011; NSDL 2011c) is designed to develop criteria and guidelines for improving the quality of resources and metadata in the NSDL collections. LAR is a framework for assessing how well educational resources, collections, and their related metadata are aligned to educational goals, curriculum, or professional development needs of teachers and learners; and how readily curated resources and collections can be embedded in tools and services that educators and students use. The guiding principles in the development of the LAR framework include criteria for assessing the pedagogic utility of resources, and criteria for assessing educational utility of metadata so that resources can be readily embedded in diverse learning applications. While the need for Learning Application Readiness has been recognized, and NSDL partners are committed to updating their metadata according to LAR guidelines once officially defined, the process of metadata revision can be time consuming and costly. In order to accelerate this process of metadata reinforcement across existing NSDL collections, we will provide LAR cataloging assistance to a core set of NSDL Pathways, and in the process design policies and practices that allow LAR compliance to scale broadly.

Next Steps:

- UCAR will convene members of the NSDL community to complete guidelines and best practices for implementing LAR standards (September 2011). These community-adopted standards will be integrated into NSDL collection development practices.
- A cadre of six Pathways partners [p. 4] will identify subsets of resources from within their existing collections plus additional resources to accession into a new **NSDL LAR Collection**.
- UCAR will partner with the Internet Scout Project at the University of Wisconsin, which currently operates NSDL's Applied Mathematics and Science Educational Resources (AMSER) Pathway. Scout will work with Pathways to systematically enhance existing descriptive metadata for learning application readiness, manage the creation and maintenance of the NSDL LAR Collection, and use the NSDL NCS system to transmit metadata to the main NSDL repository.

+ Alignment to Education Standards: Common Core Collections

The Common Core State Standards for Mathematics and English Language Arts (ELA) were released by the Council of Chief State School Officers and the National Governor's Association in Fall 2010 (NGA Center 2010). Common Core is now being widely adopted by states, to which they have or will map their own state standards. Concurrently, the National Research Council is developing Next Generation Science Standards (NGSS) (Achieve 2011b), scheduled for full release in Fall 2012. The level of use for any digital learning resource, fee-based or open, is quickly being fated by its relevancy to these new national standards. NSDL released a pilot Math Common Core Collection in August 2010, in partnership with AAAS Project 2061 and Internet Scout (NSDL 2011b). The collection now has 279 resources addressing an initial set of conceptual strands within the standards. Despite limited coverage, the Math Common Core collection has quickly become one of the most popular sections of NSDL.org, and is functioning as a test set of contextualized resources for establishing metadata and paradata exchange with partners in STEM Exchange and Learning Registry projects [pp. 8-10].

While expert-generated associations of content with educational standards have strong practical value, NSDL has also become increasingly interested in finding new approaches to expressing the more granular utility of digital resources—emerging from tacit criteria educators use to judge for themselves whether a learning object is adequate to support a given standard. Thus, we propose to investigate what information about a resource is most valuable for determining applicability to standards, and to develop new methods for representing standards “alignments” that detail a range of facets related to the content, pedagogy, reading level, interactivity, and other aspects of resources that either enhance or detract from their instructional usefulness.

As a key element of transitioning NSDL's relevancy and utility to meet new demand-side pressures for Common Core and NGSS aligned content, we wish to complete our coverage of resources mapped to all grade bands and concept strands within the Math Common Core, the relevant areas of the ELA Common Core, and prepare for the release of similar standards in science. To expedite the expansion of NSDL Common Core Collections, UCAR will offer standards alignment assistance to the core group of Pathways, and in the process design policies and practices that allow educational standards correlation processes to scale more broadly.

Next Steps:

- UCAR will partner with the Educational Digital Libraries (EDL) group at Ohio State University, which currently operates NSDL's Middle School Portal /MSP2 Pathway. EDL will work with Pathways to identify candidate resources within their collections to be accessioned into distinct **NSDL Common Core Collections** that will be managed by Internet Scout.
- EDL will work with UCAR to identify additional resources from outside NSDL that could be added to collections to complete concept and grade level coverage, and enhance the number of assessment materials, bilingual resources, serious gaming, and mobile learning apps in NSDL.
- UCAR will partner with the non-profit Achieve to pilot a set of rubrics they have developed to evaluate different facets and granularities of resource correlation to standards. EDL will use the pilot rubrics to create annotations for resources that describe their embodiment of standards.
- EDL will evaluate the relevance of resources to standards, catalog appropriate alignments with standards identifiers and richer annotations, and share alignment data to NSDL via Internet Scout.
- UCAR and EDL will proactively prepare metadata frameworks and alignment processes, informed by discussions with Achieve as they develop the Next Generation Science Standards.

+ Paradata

Up to this point, digital library advancements have been achieved largely by extending traditional library models for information architecture and management, with a particular emphasis on formalized, expert-generated metadata. The digital library community successfully shares their descriptions of resources, but feedback loops about how resources are used, reused, and valued by educators have been sparse (JISC 2011a; JISC 2011b). As a result, it has been difficult to judge the impact of digital resources on teaching and learning in distributed environments, or to ascertain how the skills and practices of educators are changing with regard to digital resource use.

In March 2010, NSDL created the construct of *paradata* to distinguish between traditional, relatively static metadata that *describes* a digital learning object and dynamic information about digital learning objects that is generated as they are used, reused, adapted, contextualized, favorited, tweeted, retweeted, shared, and otherwise diffused via social media and similar activities through which educational users interact with resources. Similar approaches such as conventional webmetrics, activity streams, and contextualized attention metadata (Najjar, et al 2007) capture some of these elements but in many different formats, and generally reference individual user data that may not be sharable. As an alternative, NSDL is employing the term paradata to describe aggregated and anonymized user activity data that is publically associated with each resource to help elucidate its potential educational utility. The paradata model has the potential to make formalized metadata just one element of a richer landscape that allows NSDL to explicate both expert-generated and user-generated information. The resulting, more educationally-situated, knowledge space can move user interactions beyond simple search, to contextualized discovery and use of resources enhanced by the networked responses of peers.

A critical milestone of our progress to-date is the creation of an XML paradata framework that proposes minimum standardization for initial paradata elements likely to be generated by online teacher communities. This first version of this framework, CommPara_1.00 (Ginger 2011), was released as an open source document in February 2011. The paradata concept and the CommPara framework are integral to the STEM Exchange and Learning Registry projects and are currently being deployed by a range of national and international digital learning efforts. NSDL is currently

receiving aggregated and anonymized paradata from three organizations, but is holding the information in a sandbox area of NSDL.org during pilot. Paradata is providing a promising alternative to traditional web analytics as a means of assessing the impact and utility of NSDL resources. As a result, a focus for the proposed work is to collaborate with Pathways and other partners to define shared practices around paradata generation, sharing, and analysis; and to enable contextual paradata interpretation for insights about users' digital content preferences.

Next Steps:

- UCAR will work with Pathways partners to establish paradata exchange from user interactions on their portals as well as to receive paradata about the use of their collections across the STEM Exchange and Learning Registry networks. This team will also address intellectual property and privacy policy development for open paradata sharing. UCAR will also investigate the feasibility of paradata exchange with the Curriculum Customization Service project at University of Colorado/UCAR as an element of their 2011 school district field trials.
- UCAR will complete development of mechanisms to visualize, parse, and perform calculations over paradata streams from multiple providers; gather input about future paradata framework iteration; establish paradata generation from NSDL.org interfaces including Common Core Collections, Science Literacy Maps, and Science Refreshers; and make all available paradata accessible through the NSDL Search API.

2.4 Redefining NSDL's Network Effects

As teachers become increasingly comfortable with integrating digital content into both traditional and innovative pedagogies, the use of online resources is increasing. Yet there is much we do not yet know about their impact. The continual improvement of cyberlearning resources, and our understanding of their efficacy, could be significantly enhanced by iterative communication between educational communities of practice about what works in real-world learning environments, and better feedback loops between educational end users and educational resource developers. Our growing relationships with district, state, and national educational resource platforms through the STEM Exchange, Learning Registry, and Curriculum Customization Service (Sumner and CCS Team 2010) initiatives provide opportunities for targeted dissemination of NSDL partners' content into the hands of teachers—for use and sharing within established trust networks and accountability systems. Combined with other NSDL efforts, such as Learning Application Readiness, that are improving the relative quality of NSDL resources and their metadata, we hope to increase overall adoption of NSDL project content and drive additional traffic back to projects' sites. In brokering these outlets for NSDL resources, we are enhancing the utility of our content to teachers on the ground, thereby creating additional points of sustainability leverage.

Our leadership on defining paradata practices and our working group participation in the Learning Registry aids our positioning among the federal agencies and other stakeholders who are convening and funding education reforms and innovations. These activities provide us with opportunities to bring the capabilities of NSDL to the table; and to demonstrate the value of our community knowledge and lessons learned, our corpus of learning content, and our unparalleled network of STEM education partners. Through this work we are positioning NSDL at the front of the conversation around the next generation of digital content.

+ The STEM Exchange

Initiated with the cooperation of NSF and the White House Office of Science and Technology Policy, the STEM Exchange (Van Gundy 2010a) is an initiative envisioned by NSDL in response to the educational transformations made possible by an increasingly networked world. The vision of the STEM Exchange calls for a new information system around digital resources that can automatically capture and display aggregated real-time user interaction data as resources are annotated, reviewed, downloaded, embedded, shared, accreted, modified, and updated by user-practitioners through their professional online communities, social media spaces, and state and districts resource portals. An initial STEM Exchange pilot project was designed to test the core concepts of (1)

expanding diffusion of NSDL resources into online communities of educators, (2) capturing data about how educators interact with NSDL resources in the context of professional collaboration platforms, and (3) integrating usage data (defined by this project as *paradata*) back into library-held metadata in order to make teacher-held knowledge openly visible in the information space around the resources. Of several dozen organizations and projects that attended the STEM Exchange startup meetings in 2010, three groups volunteered to pilot these ideas in their teacher-to-teacher peer networks: Butte County Office of Education, Florida State University, and Intel Corporation.

NSDL partnered with the Center for the Advancement of Digital Resources in Education (CADRE) group at the Butte County (California) Office of Education, including successfully connecting their *Brokers of Expertise* (CA Dept of Education 2011a) and *CTEonline* (CA Dept of Education 2011b) teacher collaboration platforms with the STEM Exchange. Since Fall 2010, they have been pulling the pilot Common Core Math Collection and other NSDL metadata of their choice into their in-house learning object management system via the NSDL DDS web service. They are returning paradata to the NSDL Data Repository via OAI-PMH. For now, these data are visible in a sandbox area of NSDL.org and not yet integrated into general user experience or search results displays. The STEM Exchange is a core model for the Learning Registry (p. 10) and we are replicating the metadata-paradata exchange with Butte County as a proof-of-concept project by testing the underlying technologies and specifications being developed by the Registry community. The Learning Systems Institute at Florida State University created a teacher collaboration site for the Florida Department of Education (Florida State Univ 2011) that is the foundation for iCPALMS, a portal for standards-based instructional resources funded as an NSDL Pathway in 2010, and scheduled for full release in Fall 2011 (Lang, Mardis et al. 2011). NSDL is working with iCPALMS to import metadata most appropriate for their users and planning mechanics of paradata export from their system. Intel Corporation has been building a new online community space for cadres of teachers who complete Intel's professional development academies, along with educators around the world. They are similarly integrating mechanisms to ingest NSDL metadata and share back paradata.

NSDL envisions the STEM Exchange as a next generation model for how educators and learners will interact with digital content that has been highly networked and contextualized by user communities. During the proposed performance period, NSDL will broaden the participation of online practitioner communities within the Exchange and use this network to disseminate NSDL LAR Collections and NSDL Common Core Collections, and to generate a new resource-base of teacher and student created content emerging from its user communities. Activity throughout the Exchange in turn generates paradata that is fed back to our core data repository and made visible alongside traditional resource metadata.

Next Steps:

- Complete integration of iCPALMS and Intel with the Exchange and connect additional groups with whom NSDL is currently in discussion, potentially including BetterLesson, KQED, Maryland Learning Object Repository, and eNet Colorado. Others from the original STEM Exchange meetings remain in the pipeline as they work with their own internal development timelines.
- The Southern Regional Education Board will engage their consortia of state virtual schools and learning object repositories around STEM Exchange and Learning Registry opportunities.
- With more partners sharing paradata, we can better test the integration of this information into existing user interfaces on NSDL.org, in search results, and elsewhere—and in turn—better understand how to interpret paradata for meaningful evaluation of resource utility.
- Complete the design of Resource Profile Pages that will serve as resource-centric dashboards of paradata from across multiple user platforms, to be made publically visible at NSDL.org.
- Continue the partnership with Butte County to operate the STEM Exchange pilot for the Learning Registry. Explore new functionalities to enhance STEM Exchange collections, services, and user experiences within the context of the Registry network.

+ The Learning Registry

Learning Registry is an inter-agency initiative led by the Office of Educational Technology at the U.S. Department of Education and the Advanced Distributed Learning Lab at the Department of Defense that is building a deeply back-end, but lightweight, “messaging” system infrastructure to support the exchange of learning resources, and their metadata and paradata (US Dept. of Education 2011a). NSDL sits on the Registry’s Technical Working Group and has participated as a core development partner since the project’s inception. In doing so, NSDL helps represent the needs of NSF grantees as a keystone user community in this open development, open source, open data ecosystem. The initiative is engaging a range of agencies, educational non-profits, and commercial content providers to generate, aggregate, contextualize, broker, and productize digital content (US Dept. of Education 2011b). A beta launch is targeted for Fall 2011.

In essence, Learning Registry is a protocol for nodal replication of data alerts across a network. It is not intended as a portal or repository, nor are teachers anticipated to interact directly with the system. Rather, service layer agents (such as NSDL) monitor streams of “data envelopes” passing through the network, act upon messages of interest, and ignore the rest. Any member of the network can receive and contribute data messages, but some agents like NSDL may choose to operate a distinct node on the Registry as a means for greater capacity to build services on top of the system. STEM Exchange is the primary proof-of-concept project for the Learning Registry technical platform, and its potential value to educational resource providers and consumers. Through a current subcontract with Department of Education contractor SRI International, we are replicating the successful resource metadata and paradata loop established with Butte County, now using Registry technology. Paradata is a central construct for the project, and the NSDL CommPara framework is being adopted as the default framework for the launch of the Registry.

Next Steps:

- NSDL will continue its leadership in refining the construct of paradata, as use cases throughout the Registry community rapidly expand.
- UCAR will continue work with Butte County to operate a STEM Exchange node on the Registry. As stewards of the LAR and Common Core Collections, Internet Scout will also be engaged to design best practices for generating NSDL data envelopes into the Registry and for processing received messages. In particular, we will set up systems to monitor paradata for resources that exist in NSDL as user activity is observed across the Registry network.
- Continue work with ED, DoD, and SRI to assist other content and data partners in connecting to the Registry technology, deep diving into issues of paradata integration and analysis, and address adoption barriers related to metadata that teacher peer networks will likely be facing. Groups whom NSDL will be helping to connect to LR in the next several months include content contributors PBS Learning Media, National Archives, the Smithsonian, and NASA; learning platforms like Agilix, Moodle, Promethean, and Sakai; and additional metadata/paradata consumers to be determined.
- NSDL is hosting the second LR PlugFest in December 2011, an event that encourages anyone in the open community to rapid test the codebase and develop new functionalities on top of it.
- Explore how NSDL can serve the broad community of NSF grantees in contributing their metadata and paradata to LR via NSDL, without needing to set up their own nodes and monitoring systems.

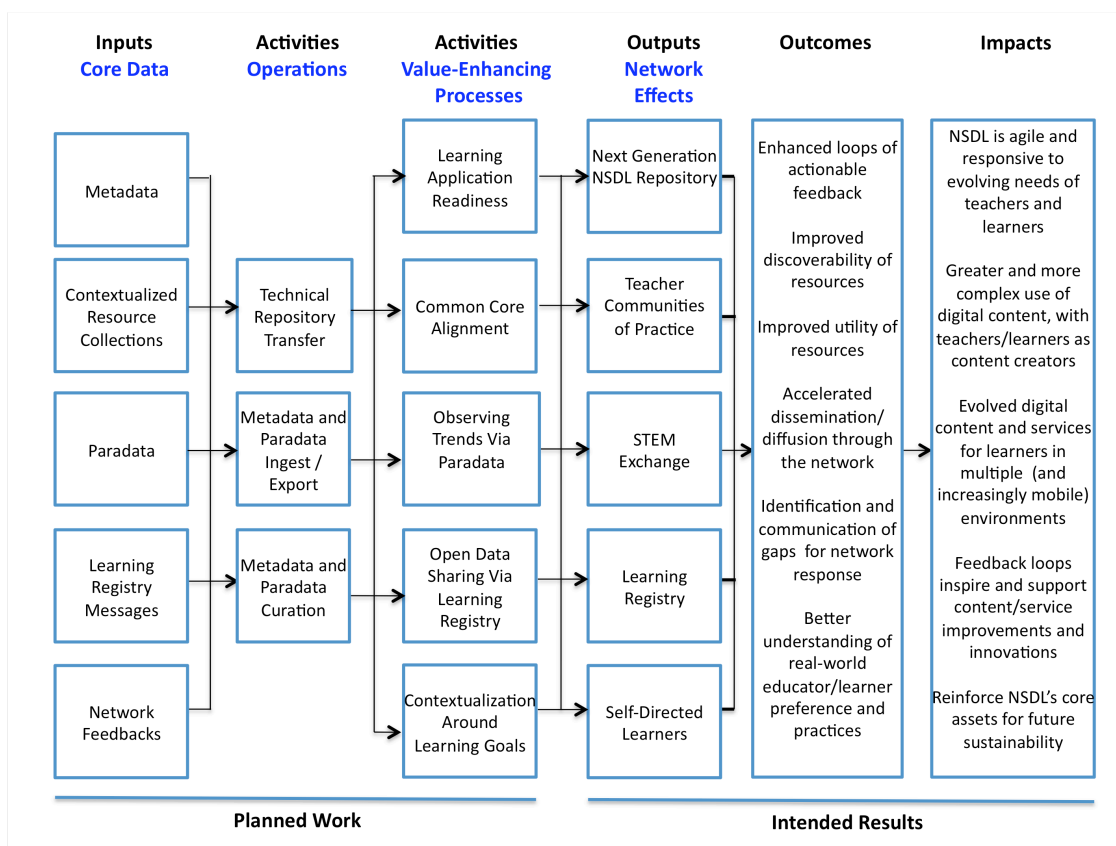
3.0 PROJECT DESIGN

3.1 Desired Outcomes and Impacts

NSDL’s ultimate goal for this project is to achieve renovations and innovations that fuel the library to support next-generation teaching and learning. By necessity, optimizing NSDL’s baseline operations and core content to be agile and responsive in a rapidly changing educational environment is at the crux of our plans. Working backwards from these objectives [Figure 2], we have designed a system that places next-generation content more efficiently into the hands of teachers—where it must be to have impact—and instruments teachers’ digital content workflows to share usage, preference, and gap data throughout the network (paradata). For the resources NSDL mobilizes into such teacher

communities to be impactful, they must be useful to highly specific user needs. For resources to be useful they must be contextualized for efficient discovery, evaluation, and adoption within the constraints of teachers' time, expertise, and curricular paradigms. The proposed work will achieve that contextualization via both expert-generated and user-generated processes for enhancing metadata, alignment to standards and curriculum, and the feedback loop of paradata.

Figure 2 – NSDL Logic Model



3.2 Evaluation Plan

The nature of the proposed work is, in many ways, translational research (Woolf 2008). Just as the medical community has recognized the importance of research that bridges scientific findings with practice-based applications to replicably improve patient outcomes, NSDL is proposing to observe practitioner behaviors during authentic use of the products of cyberlearning R&D. Analogous to developments in medical research, attention to date has been focused on creating “treatments” for educational problems and in designing semi-rigid methodologies that leverage specific functionalities of new technologies (e.g., wikis, interactive whiteboards, gaming, student response system “clickers”). In contrast, the system-wide feedbacks built into the proposed activities lend themselves well to the *practice-based research* aspect of translational investigations, which Woolf describes as “often necessary before distilled knowledge (e.g., systematic reviews, guidelines) can be implemented in practice.” Through this project, UCAR will explore the critical nature of implementation that characterizes impacts in cyberlearning, what Woolf frames as the “human behavior and organizational inertia, infrastructure and resource constraints, and the messiness of proving the effectiveness of ‘moving targets’ under conditions that investigators cannot fully control.”

Evaluation for the project will focus on the impact of making Common Core Collections available through the STEM Exchange network of online teacher communities. Survey data from Scholastic/Gates Foundation (Scholastic 2010), PBS (PBS 2010), Project Tomorrow (Evans 2010; Evans 2011b), the Curriculum Customization Service project (Sumner and CCS Team 2010) and others, demonstrate that teachers are using digital content more frequently, in increasingly complex ways, and they trust their peers as sources of information about what is effective significantly more than the claims of content providers. How then, will the addition of paradata information about resources affect teachers' experiences in discovering, sharing, and using digital resources?

Metiri Group will design an evaluation study to provide formative and summative information on the use of NSDL mathematics resources (with disaggregation of those aligned to the Common Core) by a select group of online teacher communities of practice (CoPs) participating in the STEM Exchange. Sample research questions include:

- How are the STEM Exchange participating CoPs mobilizing the use of NSDL resources (especially those aligned to the Common Core) within their community platforms?
- What are the usage patterns of NSDL digital resources by groups of teachers, and curriculum specialists in public schools in select communities as they transition to the Common Core in mathematics? How does such usage change over time, as the participating CoPs/states implement the Common Core for mathematics?
- How does the usage of NSDL resources by participants in the select CoPs vary by user characteristics, resources characteristics, and the presence of paradata?
- What elements of paradata are most useful to educators for inferring potential resource utility?

3.3 Milestones

Figure 3: Project Timeline

FY 2012 – Q1/Q2	FY 2012 – Q3/Q4	FY 2013 – Q1/Q2	FY 2013 – Q3/Q4
<ul style="list-style-type: none"> - Convene Pathways for project planning and to finalize frameworks and related policies for LAR and paradata - Move repository infrastructure from Cornell to UCAR/cloud services - Identify subsets of Pathways collections for processing to LAR and Common Core Collections - Begin LAR cataloging and standards alignments - Begin instrumenting Pathways portals and NSDL.org for paradata - Ready the NSDL node on the Learning Registry for public beta launch - Begin data collection for evaluation study 	<ul style="list-style-type: none"> - Complete LAR cataloging and standards alignments - Make new collections available to STEM Exchange Partners - Develop framework for correlating resources to Next Generation Science Standards - Complete work on graphical user interface to visualize paradata aggregated across the network - Complete data gathering and analysis for evaluation - Connect additional community/state partners to STEM Exchange - Participate in Learning Registry code and practices refinements 	<ul style="list-style-type: none"> - Pathways partners project meeting - Prepare interim results for publication - Continue to participate in Learning Registry code and practices refinements - Explore opportunities to offer value-added services on top of NSDL's Learning Registry node 	<ul style="list-style-type: none"> - Share results of Pathways pilots with broader NSDL community and engage new project partners for LAR/Standards/STEM Exchange/Registry processes - Continue to add resources as appropriate to new collections - Continue to receive and share out paradata, and interpret data patterns

3.4 Key Personnel

Kaye Howe (PI) is Director of the NSDL Resource Center (RC) at UCAR. She will oversee project management, operations, and administration of the work. **Susan Van Gundy** (Co-PI) is Deputy Director of the RC, with responsibility for strategic partnership development. She is the architect of the NSDL STEM Exchange initiative, and Technical Working Group member for the Learning Registry. She will have primary project management, partnership collaboration, and coordination responsibilities for the conduct of the proposed work, and will participate in best practices and

guidelines development for paradata exchange, LAR guidelines, and related STEM Exchange/Learning Registry interactions. **Mary Marlıno** (Co-PI) is the Director, Integrated Information Services (IIS) (program home of NSDL Technical Network Services). She has oversight for collaboration and coordination of the technical infrastructure transition and curation activities of the NSDL from their current location at Cornell University to hosting at UCAR. **John Weatherley** (Co-PI) is a Senior Software Engineer for IIS, with responsibility for transitioning the NSDL data repository infrastructure, migrating all systems, services, and repository content to UCAR locations and/or commercial cloud systems, with related code, metrics and vitality tools. He will work with Pathways and STEM Exchange/Learning Registry partners for paradata exchange, including security and performance monitoring systems. **Katy Ginger** (Co-PI) is NSDL Metadata Architect and Collections Manager, with responsibility for collections integration, curation, and assessment; NAB oversight; metadata/paradata framework development; metadata implementation; controlled vocabulary and best practices development; and tool/collection training. **Karon Kelly** (Senior Personnel) is the Associate Director, IIS. She will oversee all collections development, collections assessment, and collections curation activities. **Eileen McIlvain** (Senior Personnel) is the manager of communications and project relations for the RC. She will have primary responsibility for coordination and documentation among UCAR and the eight Pathways partners, including facilitation of the NSDLnetwork.org community networking site. **Cheryl Lemke** (Evaluator), President and CEO of Metiri Group, is the evaluation specialist for the proposed work. She has a 25-year background in public policy for K12 learning technology, working at national, state, and local levels with education stakeholders on leadership in technology. She will conduct an evaluation study providing formative and summative reports on use of NSDL mathematics resources, with disaggregation of those aligned to Common Core, by a select group of district and states participating STEM Exchange.

3.4 Sustainability

The proposed project is designed to complete the transition of NSDL from NSF program to fully realized and independently sustainable organization. When completed, the updated technologies, policies, resources, and value-enhancing services will position NSDL—as well as Pathways and other partners in the distributed network—to regain competitive advantage in a digital content marketplace that has diversified substantially since NSDL's inception. The goals and activities within the proposal emerged, in part, from a series of planning conversations NSDL convened with Pathways and other projects about sustaining the library. Through their participation, Pathways partners are committing to a collaborative future for NSDL, and demonstrating confidence that proposed activities resonate with their own sustainability prospects. The NCAR Library at UCAR is prepared to provide long-term continuity of the repository infrastructure. In addition, UCAR has established a small group of advisors from corporate, government, and philanthropic institutions to accelerate business planning and the pursuit of viable sustainability models.

4.0 Intellectual Merit and Broader Impacts

Intellectual Merit

Perennial challenges for cyberlearning projects include integrating digital learning resources meaningfully into the workflows of users, and measuring the impact of those resources on educational practice. The proposed work addresses these issues with non-traditional approaches that leverage the collective expertise of NSF's NSDL grantees community, along with networked systems of education practitioners, and their online collaborative workspaces. The project will yield new NSDL collections for Learning Application Readiness and Common Core alignment that will be openly shared via the STEM Exchange, a growing consortium of online teacher communities, state education portals, and open educational resource (OER) providers. Through the STEM Exchange, aggregated and anonymized data streams about resources usage (defined by NSDL as paradata) will be returned to NSDL as teachers interact with digital content in their online collaborative workflows. Paradata will be shared as open data reassociated with resources as they are continually shared across the network. A major initial activity for the project will be relocating NSDL's technical infrastructure from Cornell University to UCAR. This will prepare the

library to evolve its potential as innovation architecture that supports the multitude of content, authorship, and resource sharing environments that now proliferate the online lives of educators and students.

Broader Impacts

The proposed work will significantly enhance the utility and discoverability of the digital resources funded by NSF through ten years of the NSDL program. Resources will be aligned to new Common Core Standards, and mapped to an emerging set of Learning Application Readiness criteria that NSDL will publish as an open framework. These processes will increase the potential for NSDL collections to be adopted into a wider range of instructional paradigms and more broadly shared through teacher peer-to-peer networks. Project activities, including the STEM Exchange, will accelerate the diffusion of digital resources through collaborative online teacher communities; capture in situ data about how users share, personalize, and recontextualize resources for their own instructional practices; and make this user activity data broadly visible to other users as an indicator of resource utility. Through involvement in the Learning Registry, NSDL is contributing to a multi-agency federal project designed to make learning resources produced by the federal government more accessible. The initiative is combining traditional metadata with paradata generated by digital systems close to the end-users to create a richer pool of data for improving recommendation and relevancy engines, and to enhance research into teacher practices and effectiveness. The transition of NSDL technical infrastructure to UCAR and commercial cloud-based services will give the library a robust, flexible, high-availability operational platform and reduce the costs associated with library operations. These factors will ultimately have a positive impact for the community, as NSDL will be positioned for more sustainable and flexible operations.

5.0 Results from Prior NSF Support:

DUE #0840845: NSDL Center for Sustaining Broader Impacts; \$4,107,523

POP: October 1, 2008 – September 30, 2012; PIs: Kaye Howe, Mary Marlino, Susan Van Gundy; University Corporation for Atmospheric Research.

In its third of four years of support, NSDL Resource Center (RC) accomplishments are rooted in the assertion that the NSDL platform is the community itself and that its work is the curation of network, services, and resources. RC activities focus on brokering partnerships, monitoring trends and practices, advocacy for NSDL, customization and contextualization of NSDL resources, putting NSDL in the path of users, and systematic data gathering to inform decision-making and sustainability. RC provides multi-level support for and engagement of the NSDL community of grantees; expansion of NSDL's reach into broader networks of partnership, and systems fostering effective use of digital resources in education. The RC has 1) conducted and coalesced new initiatives (STEM Exchange and Learning Registry), convened stakeholder meetings producing proof-of-concept demonstrator projects; 2) collaborated with Technical Network Services in the Learning Application Readiness initiative; 3) engaged the NSDL network in productive meetings and workshops supporting sustainability (Pathways Meetings 2009/2010; NSDL Annual Meetings 2009/2010; community interviews Spring 2011, Planning Meeting April 2011, LAR workshop May 2011); 4) is conducting revision of NSDL web presences (nsdl.org, nsdlnetwork.org); 5) created NSDL Common Core-aligned mathematics collection; created *NSDL on iTunes U* collection of audio and video content, and fostered other contextualized collection building with Pathway partners; 6) conducted professional development and collaboration via webinars, conference attendance (AAAS, NMSA, NSTA, ISTE); PI meetings (CCLI/TUES, ITEST, Noyce Scholars); convened related stakeholder meetings (Oct 2009): *Cyberlearning Tools for Climate Education: Community Needs Assessment* workshop and *Geocyberlearning Workshop*. Publications include:

- Mardis, M. and K. Howe (2010). STEM for Our Students: Content to Co-conspiracy? *Knowledge Quest* 39(2): 8-11.
- McIlvain, E. (2010). NSDL as a Teacher Empower Point: Expanding Capacity for Classroom Integration of Digital Resources. *Knowledge Quest* 39(2): 54-63.
- Best Practices for Metrics Collection and Analysis: Final Report of the NSDL Metrics Working Group (Aug. 2010)

Supplement to DUE #0840845 - NSDL Center for Sustaining Broader Impacts: New Approaches to NSDL Resource Contextualization and Dissemination: Phase 1 – Mapping NSDL Resources to the Common Core Standards; \$146,422 POP: February 1, 2010 – September 30, 2012; PIs: Kaye Howe; UCAR.

This supplement enabled the creation of a premiere collection of open education resources from NSDL explicitly related to the Common Core Standards in Math. The work included creation of a process for resource alignment that can be implemented for additional content areas as new Common Core/Next Generation standards are developed; with ability to make these collections available through NSDL and other educational resource providers concurrent with public release of each set of standards. Partnering with Internet Scout at the University of Wisconsin, the project reviewed and identified candidate resources for standards mapping process, contributed to expanding the nomenclature for describing how resources map to standards; advanced the NSDL data repository framework to represent the information structure of the Common Core documents; engaged stakeholder organizations and agencies for additional feedback on processes and outcomes, and established processes that serve as models for future contextualization and dissemination. NSDL Math Common Core collection debuted in August 2010. There are currently 279 aligned resources, with 500 additional resources in preparation.

DUE #0840744 – NSDL Technical Network Services: A Cyberinfrastructure Platform for STEM Education; \$7,293,352; POP: October 1, 2008 – September 30, 2012. PIs: Carl Lagoze, Cornell University; Michael Wright, Co-PI, UCAR; Tamara Sumner, Co-PI, University of Colorado.

Technical Network Services operates the infrastructure of NSDL, develops tools and services for creating and curating collections of digital resources for discovery and delivery via NSDL.org, APIs, and other portals/applications; provides support, training, and consultation on collection development and use of tools and services; and creates and evaluates exemplar applications that help users to optimize experiences with NSDL resources. Key accomplishments: 1) Denver Public Schools (DPS) Field Trial – research on use of the Curriculum Customization Service (CCS) application, providing differentiated, customized instruction combined with curriculum-associated interactive digital resources. Results showed that teachers integrated resources in their teaching with greater frequency, confidence, and effectiveness. 2) NSDL Collections – completion of a major collection review, analysis, and deaccessioning effort, streamlining of NSDL content for focus on utility for teaching and learning; development of Learning Application Readiness (LAR) as approach for assessing collection quality and suitability for programmatic implementation in tools and services; analysis of library metadata and normalization of vocabularies across collections. Vitality reports to collection providers and normalization processes improving NSDL search results for more accurate and consistent results; 3) Development of annotation framework and 4) Development of paradata framework for ingest of usage data. Publications include:

- Devaul, H. and S. Clark (2011). NSDL Audience Survey Report: Who Uses NSDL? Boulder, Colorado, University Corporation for Atmospheric Research (UCAR); NSDL Technical Network Services: 32. URL: http://nsdlnetwork.org/sites/default/files/NSDLUserSurvey2011_distribute.pdf
- Devaul, H. and S. Clark (2010). NSDL Audience Survey Report: Who Uses NSDL? Boulder, Colorado, University Corporation for Atmospheric Research (UCAR); NSDL Technical Network Services: 15.
- Devaul, H. (2010). Community Evaluation Summary Report. Boulder, Colorado, University Corporation for Atmospheric Services (UCAR), NSDL Technical Network Services. URL: [http://nsdlnetwork.org/sites/default/files/TNSEvalSpring2010\(distribute\).pdf](http://nsdlnetwork.org/sites/default/files/TNSEvalSpring2010(distribute).pdf)
- Davis, L., H. Devaul, T. Sumner and J. Weatherley (2009). Curriculum Customization Service: Results of a Pilot Study and Future Enhancements. 4th International Conference on Open Repositories, Atlanta GA, Georgia Institute of Technology.

References – Repositioning NSDL for the Next Generation of Digital Learning

Achieve (2011a). Achieve, Inc.,. Retrieved 24 June 2011 from <http://www.achieve.org/>

Achieve (2011b). Next Generation Science Standards. Retrieved 25 June 2011 from <http://www.achieve.org/next-generation-science-standards>

ADL (2011). Advanced Distributed Learning Lab, US Dept of Defense. Retrieved 24 June 2011 from <http://www.adlnet.gov/Pages/Default.aspx>

BetterLesson (2011). BetterLesson. Retrieved 24 June 2011 from <http://betterlesson.org/>

Bower, R. and E. Almsy (2011). Applied Math and Science Education Repository (AMSER). Retrieved 23 June 2011 from <http://amser.org>

CA Dept of Education (2011a). Brokers of Expertise. Retrieved 25 June 2011 from <http://www.myboe.orghttp://www.myboe.org>

CA Dept of Education (2011b). CTEOnline. Retrieved 25 June 2011 from <http://cteonline.org>

CADRE (2011). Center for the Advancement of Digital Resources in Education. Retrieved 24 June 2011 from <http://cadreonline.org/>

Devaul, H. (2010). Community Evaluation Summary Report. University Corporation for Atmospheric Research, Boulder, Colorado. Retrieved 24 June 2011 from [http://nsdlnetwork.org/sites/default/files/TNSEvalSpring2010\(distribute\).pdf](http://nsdlnetwork.org/sites/default/files/TNSEvalSpring2010(distribute).pdf)

Devaul, H. and S. Clark (2010). NSDL Audience Survey Report: Who Uses NSDL? University Corporation for Atmospheric Research, Boulder, Colorado. Retrieved 24 June 2011 from <http://nsdlnetwork.org/sites/default/files/UserSurvey2010-WhoUsesNSDL.pdf>

Evans, J. (2010). Unleashing the Future: Educators "Speak Up" about the use of emerging technologies for learning. Project Tomorrow, Irvine, California. Retrieved 24 June 2011 from <http://www.tomorrow.org/speakup/pdfs/SU09UnleashingTheFuture.pdf>

Evans, J. (2011a). The new 3 E's of education: Enabled, engaged, empowered. How today's educators are advancing a new vision for teaching and learning. Project Tomorrow, Irvine, California. Retrieved 24 June 2011 from http://www.tomorrow.org/speakup/pdfs/SU10_3EofEducation_Educators.pdf

Evans, J. (2011b). The new 3 E's of education: Enabled, engaged, empowered. How today's students are leveraging emerging technologies for learning. Project Tomorrow, Irvine, California. Retrieved 24 June 2011 from [http://www.tomorrow.org/speakup/pdfs/SU10_3EofEducation\(Students\).pdf](http://www.tomorrow.org/speakup/pdfs/SU10_3EofEducation(Students).pdf)

Florida State Univ (2011). CPALMS Retrieved 25 June 2011 from <http://floridastandards.org>

Ginger, K. and L. Goger (2011). Evaluating the National Science Digital Library (NSDL) for Learning Application Readiness, pre-publication. Boulder, Colorado, University Corporation for Atmospheric Research.

Ginger, K. M. (2011). Community Paradata (Usage Data) Metadata Format: 2011. Boulder, Colorado, National STEM Education Distributed Learning program, University Corporation for Atmospheric Research. Retrieved 24 June 2011 from http://ns.nsd.org/ncs/comm_para/1.00/

- Intel (2011). Intel Corporation. Retrieved 24 June 2011 from http://www.intel.com/index.htm?en_US_01
- JISC (2011a). OER Impact Study: OER reuse landscape. Retrieved 29 June, 2011, from <http://oerblog.conted.ox.ac.uk/?p=32>
- JISC (2011b). Pilot Phase Pedagogy and End Use Issues. JISC Open Educational Resources Programme - Phase 2. Retrieved 29 June, 2011, from <https://oersynth.pbworks.com/w/page/29749634/Pilot-Phase-Pedagogy-and-End-Use-Issues>
- Khoo, M. (2006). NSDL User Survey, 2006. Boulder, Colorado. Retrieved 25 June 2011 from http://eval.comm.nsd.org/docs/06_user_survey.pdf
- Lang, L. (2011). Learning Systems Institute. Retrieved 24 June 2011 from <http://www.lsi.fsu.edu/>
- Lang, L., M. Mardis and R. Razzouk (2011). iCPALMS Pathway. Retrieved 25 June 2011 from <http://www.icplams.org>
- Ledley, T. S., F. Niepold, M. McCaffrey, S. Buhr, C. A. Manduca, S. Fox and C. Howell (2011). CLEAN: Climate Literacy and Energy Awareness Network Pathway. Retrieved 23 June 2011 from <http://www.cleanet.org/>
- Lightle, K. (2011). Middle School Portal: Math and Science Pathways (MSP2). Retrieved 24 June 2011 from <http://msteacher2.org/>
- Mason, B. (2011). ComPADRE: Physics and Astronomy Pathway. Retrieved 23 June 2011 from <http://www.compadre.org/portal/>
- Moore, J. and J. Holmes (2011). ChemEd DL: Chemistry Education Pathway. Retrieved 23 June 2011 from <http://www.chemeddl.org/>
- Najjar, J., M. Wolpers and E. Duval (2007). Contextualized attention metadata. *D-Lib Magazine* **13**(9/10).
- NGA Center (2010). Common Core State Standards Initiative. Retrieved 25 June 2011 from <http://www.corestandards.org/>
- NSDL (2001). Pathways to Progress: Vision and Plans for Developing the NSDL. C. A. Manduca, F. P. McMartin and D. W. Mogk. Boulder, CO, National Science Digital Library: 31. Retrieved 3 September 2010 from http://onramp.nsd.org/eserv/onramp:35/pathways_to_progress.pdf
- NSDL (2005 - 2011). What are NSDL Pathways? Retrieved 24 June 2011 from <http://nsdl.org/about/?pager=pathways>
- NSDL (2007). Response in Support of the National Science Board Action Plan for STEM Education. Boulder, CO. Retrieved June 25, 2011 from http://onramp.nsd.org/eserv/onramp:39/nsdl_nsb_response.pdf
- NSDL (2011a). For Developers NSDL web site. Retrieved 25 June, 2011 from <http://nsdl.org/contribute/?pager=developers#create>
- NSDL (2011b). NSDL Math Common Core Collection. Retrieved 25 June 2011 from <http://nsdl.org/browse/commcore/math/>
- NSDL (2011c). What is Learning Application Readiness? Retrieved 25 June 2011 from <http://nsdlnetwork.org/LAR>

NSF (2008). Fostering learning in the networked world: The cyberlearning opportunity and challenge: A 21st Century agenda for the National Science Foundation. Arlington, VA. NSF08204. Retrieved 24 June 2011 from http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf08204

NSF (2010). National STEM Education Distributed Learning program. Retrieved 23 June 2011 from http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5487&org=DUE&from=home

NSF (2011). Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics. National Academies Press, Arlington, Virginia. Retrieved 24 June 2011 from http://www.nap.edu/catalog.php?record_id=13158

OET (2011). Office of Educational Technology, U.S. Dept of Education. Retrieved 24 June 2011 from <http://www2.ed.gov/about/offices/list/ost/technology/index.html>

OSTP (2011). Office of Science and Technology Policy, The White House. Retrieved 24 June 2011 from <http://www.whitehouse.gov/administration/eop/ostp>

PBS (2010). Deepening Connections: Teachers Increasingly Rely on Media and Technology. PBS and Grunwald Associates, Arlington, Virginia. Retrieved 25 June 2011 from http://www.pbs.org/about/media/about/cms_page_media/182/PBS-Grunwald-2011e.pdf

Porcello, D. and S. Hsi (2011). Science and Math Informal Learning Educators Pathway. Retrieved 24 June 2011 from <http://howtosmile.org/>

Scholastic (2010). Primary Sources: America's Teachers on America's Schools. Scholastic and Bill and Melinda Gates Foundation, New York. Retrieved 27 June 2011 from <http://www.scholastic.com/primarysources/download.asp>

Sicker, T. (2011). Teachers' Domain. Retrieved 24 June 2011 from <http://www.teachersdomain.org/>

SREB (2011). Southern Regional Education Board. Retrieved 24 June 2011 from <http://www.sreb.org/>

Sullivan, J., R. Reitsma, M. Mooney, P. Klenk and M. N. Cyr (2011). TeachEngineering Resources for K12 - Engineering Pathway. Retrieved 23 June 2011 from <http://teachengineering.org/index.php>

Sumner, T. and CCS Team (2010). Customizing science instruction with educational digital libraries. Joint Conference on Digital Libraries 2010. Gold Coast, Queensland, Australia, ACM/IEEEAccess 2010.

US Dept. of Education (2011a). Learning Registry Retrieved 25 June 2011 from <http://www.learningregistry.org/>

US Dept. of Education (2011b). Learning Registry About site. Retrieved 27 June 2011 from <http://www.learningregistry.org/.about>

Van Gundy, S. (2010a). NSDL STEM Exchange Initiative. Retrieved 25 June 2011 from <http://nsdlnetwork.org/stemexchange>

Van Gundy, S. (2010b). The STEM Exchange: Enabling next generation approaches for community access to federally funded online materials. Concept Paper. University Corporation for Atmospheric Research, Boulder, Colorado. Retrieved 24 June 2011 from <http://nsdlnetwork.org/stemexchange/concept-paper>

Wolf, S. H. (2008). The meaning of translational research and why it matters. Journal of the American Medical Association (JAMA) **299**(2): 211-213.