Collaborative Context Creation in NSDL 2.0

Dean B. Krafft
Cornell University Information Science
301 College Ave.
Ithaca, NY 14850
607-255-9214
dean@cs.cornell.edu

Ellen J. Cramer
Cornell University Information Science
301 College Ave.
Ithaca, NY 14850
607-254-8952
elly@cs.cornell.edu

ABSTRACT
With the introduction of NSDL 2.0, the National Science Digital Library project has created a platform that supports the collaborative creation and dissemination of context around the high quality resources in the library. This paper describes how we are extending and modifying standard, open-source Web 2.0 social networking and collaboration tools, such as wikis and blogs, to allow library users to easily add resources, metadata and context to the library.

Categories and Subject Descriptors
H.3.7 [**Information Systems**]: Digital Libraries – *Collection, Dissemination, Systems Issues, User Issues.*

General Terms
Design, Human Factors.

Keywords
NSDL, blogs, wikis, education.

1. INTRODUCTION
The National Science Digital Library (NSDL) project [2, 21] was created by the National Science Foundation "to provide organized access to high quality resources and tools that support innovations in teaching and learning at all levels of science, technology, engineering, and mathematics education." The NSDL Core Integration team at Cornell University designs and implements the technical infrastructure and tools for the NSDL library.

The NSDL project has recently released its second major version of the library, NSDL 2.0 [10]. The architecture for this version, based on the Fedora [1] repository system, supports a number of significant new features. Taken together, these allow creating tools that build a web of context around and among resources in the library. This context can include such things as organizing a set of resources into a lesson plan, correlating resources to educational standards, annotating resources with reviews, and relating them to current events or other work in the field.

Providing context for the resources in the library is critical to enabling library users to teach about them, learn about them, and understand them. The act of teaching is really that of creating a context for facts, concepts, and resources. When scientists advance their field, they do so in the context of all the related work that has preceded theirs. NSDL 2.0 allows us to explicitly capture this context in the library, to ~~the~~ benefit ~~of~~ all library users. Moreover, it potentially allows ~~-~~ any learner to explore the context, follow the connections, and add new connections and context of their own.

One of the key paradigms of Web 2.0 [14] is engaging a community of users in creating content that is useful to all. With well over 2 million resources in the library, it is not possible for ~~the~~ a relatively small central ~~NSDL~~ staff to add significant context to even a small fraction of them. However, it is possible to build or adapt tools that enable the entire NSDL community to add this context and create a major new source of value in the library.

In this paper, we describe how we are adapting standard web tools, such as blogs, wikis, and bookmarking systems, to create an ecosystem of collaborative content and context creation within the overall framework of the library. We believe that combining high-quality, human-selected resources [this suggests a departure from current collection systems/practices. Although this is the point of NSDL 2.0, it may be confusing—will NSDL now only accept hand-selected resources?-- to the those who are familiar with how NSDL 1.0 built collections.] with community-created context will transform the nature of digital libraries, dramatically increasing their value and utility to scientists, engineers, teachers, librarians, and students everywhere.

2. RELATED WORK
This paper builds on extensive work over the past six years in creating the NSDL. Work on the initial version of the NSDL architecture is described in [9], and a discussion of the design and motivation for NSDL 2.0 is presented in [12] and [10]. Earlier related work on annotation systems, resource linking, and the importance of context for learning is extensively discussed and cited in [10] and will not be repeated here.

There are a very large number of examples of collaborative creation of authoritative content using Web 2.0 tools. For wiki-based systems, Wikipedia[1] is certainly the best known. In the area of bookmarking and tagging, Connotea[2], developed by the Nature Publishing Group, allows scientists to share and annotate references to the literature. There are many other blog, wiki and bookmarking systems, but, in general, these are standalone resources, where a single tool is used to create and modify the content. Relationships within and among them are mostly at the level of the web itself, implemented as URLs.

From the point of view of the community of contributors, this paper discusses the creation of object-centered social networks, where the library resources become the objects of sociality. Zengestrom [5] argues that social networks succeed when they are

[1] http://en.wikipedia.org

[2] http://www.connotea.org

Conference'04, Month 1–2, 2004, City, State, Country.

seen as people connected by a shared object, giving Flickr, where photos are the object, as one example.

There is also work at the intersection of education, digital libraries and Web 2.0 tools. Frumkin [6] discusses using wikis in digital libraries, and speculates on applying a wiki as a digital library annotation tool. Milson and Krowne [13] describe re-conceptualizing the digital library as a dynamic, commons-based peer production knowledge environment, they and examine using PlanetMath[3] and Noösphere [8], a wiki-like collaborative environment, in an instructional setting. Downes [17] describes a vision of *e-learning* that comes close to the vision of NSDL 2.0:

> "What happens when online learning ceases to be like a medium, and becomes more like a platform? What happens when online learning software ceases to be a type of content-consumption tool, where learning is 'delivered', and becomes more like a content-authoring tool, where learning is created? … The e-learning application, therefore, begins to look very much like a blogging tool. It represents one node in a web of content, connected to other nodes and content creation services used by other students. … It becomes, indeed, not a single application, but a collection of interoperating applications—an environment rather than a system."

With NSDL 2.0, we seek to create an ecosystem of open tools, available to students, teachers and scientists, that integrate~~s~~ with and build~~s~~ on ~~the high-quality resources in the~~ NSDL resources and that allow~~s~~ learning to be created, not just consumed.

3. CREATING CONTEXT IN NSDL 2.0

3.1 Overview of NSDL 2.0

A full description of the architecture of NSDL 2.0 can be found in [10, 11], but we will briefly review the key concepts here. The library is a set of digital objects and relationships, stored in the Fedora-based NSDL Data Repository (NDR) and accessed through a web services API. The primary digital objects are: a resource object that either contains or specifies content (e.g. a web page, a journal article, a dataset); a metadata object that contains structured statements about a resource (e.g. author, title, audience); an aggregation object that collects resources, metadata objects, and other aggregations together in a set; and an agent object that specifies the source for metadata statements and the selector for aggregations. In addition to the structural relationships among these objects implied by the descriptions above, NSDL 2.0 also supports other relationships among the objects. For creating context, the most important of these is the annotation relationship between resources.

Figure 1 illustrates a set of conceptual objects and relationships in the library. One agent, the Cornell Center for Materials Research (CCMR) is acting as a metadata provider for both publication metadata and dataset metadata on two resources. The Materials Digital Library (MatDL) agent is acting as the selector for two collections (aggregations), each containing resources. Finally, there are two annotation relationships, "Cites", between the publication resource and both the dataset resource and the code resource.

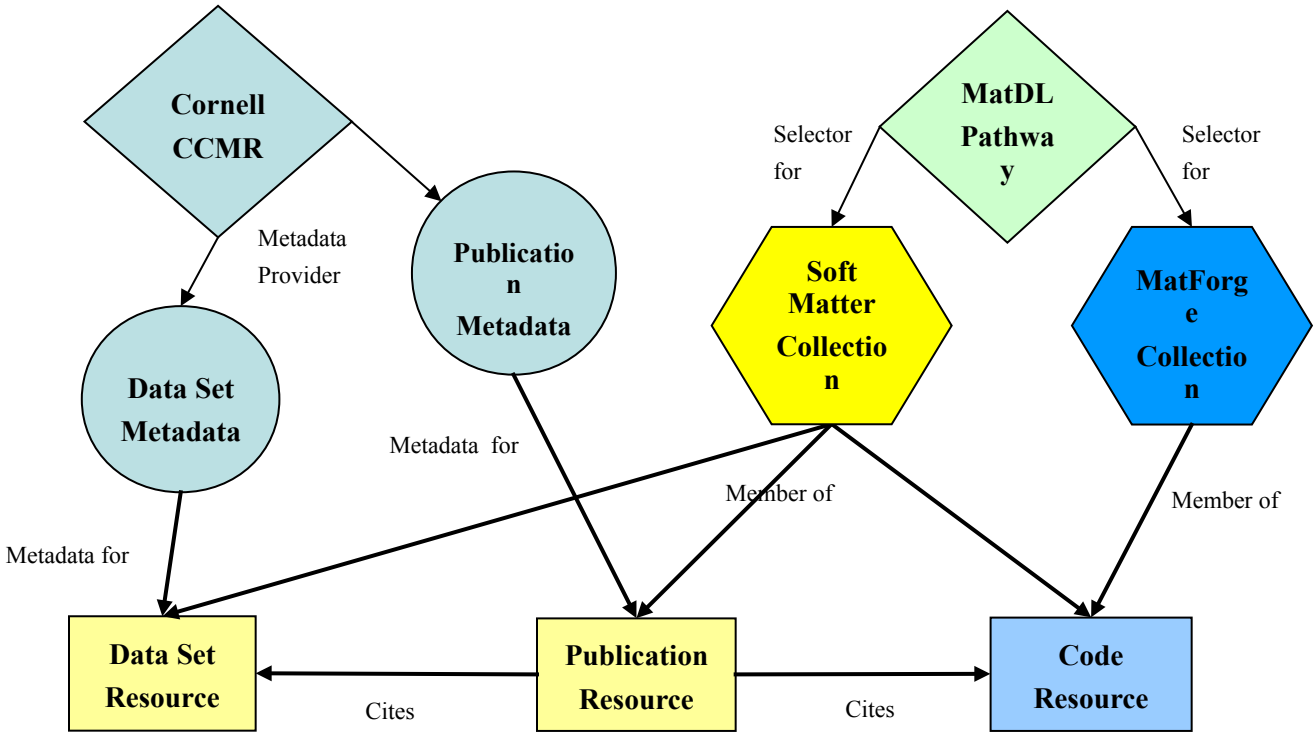

Figure 1 - Sample NDR Objects and Relationships

NSDL 2.0 also has the capability to support sophisticated, arbitrary queries over the relationship structure of the repository.

[3] http://planetmath.org

For example, given the data set resource of Figure 1, it is possible to build a query to find related code resources, and discover the code resource two links away through both the publication and the Soft Matter collection. At a technical level, relationships are expressed in the repository as Semantic Web-style RDF triples[7]. They are currently held in an MPTStore[4]-based triplestore, supporting simple queries with complex query support (a subset of SPARQL) in development, and also in a Kowari[5] triplestore, which allows complex iTQL queries over the triples[19].

NSDL 2.0 is currently in production and accessible through http://nsdl.org. As of January 15, 2007, the library contains 2.63 million resource objects, 1.98 million metadata objects, 825 aggregation objects, and 729 agents. All resources and other objects are uniquely and permanently identified using *handles* provided by the CNRI Handle System®[6]. Web services access to the library is available through the NDR API[7], with public/private key authenticated access to allow registered agents to add and update metadata and aggregations.

3.2 Resources, Metadata, and Context

The collaborative tools described in this paper allow users to add three distinct, but interrelated, kinds of information to the library. They can add new resources, either by directly depositing content into the repository or by providing a link or specification of a resource available on the web or elsewhere. They can add structured metadata, such as the appropriate audience level, a geo-reference, or a subject category, that describes a resource already in the library. Finally, they can add explicit or implicit context to resources and to metadata statements about those resources.

Within the NDR, context can take a number of forms. It can be structural context, where, for example, the user creates an aggregation of the top ten astronomy resources for middle-school students. This will both make explicit statements about the resources themselves, in the astronomy example, the subject classification that the user gives to the aggregation applies to its members, and it will make implicit statements, such as that if a user is interested in one resource in that aggregation, then they are likely to find that another resource in the aggregation is also relevant.

Context can also be expressed by more arbitrary relationships within the NDR. For example, one resource could be a review of another resource. A lesson plan could include, and therefore annotate, a number of library resources. A publication can cite a number of other publications. And a particular AAAS Science Literacy benchmark[3] could be related to a number of resources appropriate to the benchmark.

While the collaborative applications and the NDR will sort out the user-provided information into different digital objects and relationships, the user of the application does not need to have any explicit understanding of this process. When the user creates a blog entry in the Expert Voices application, or a wiki page in OurNSDL, they will frequently be creating resources, metadata, and relationship context, while simply using the tools in a customary and comfortable way.

[4] http://mptstore.sourceforge.net

[5] http://www.kowari.org

[6] http://www.handle.net

[7] Documented at http://ndr.comm.nsdl.org

3.3 NSDL 2.0 and Web 2.0

"The central principle behind the success of the giants born in the Web 1.0 era who have survived to lead the Web 2.0 era appears to be this, that they have embraced the power of the web to harness collective intelligence"[14].

In its first instantiation, released in 2001, NSDL was strictly a traditional provider of information. All the data flow was from the collections, through the central library, and out to the end users. There was no opportunity for the library to harness the collective intelligence of our users, or indeed of any broader community of potential individual contributors. Since well before Tim O'Reilly made the statement quoted above, the NSDL CI team has been working to design and build the infrastructure to enable our users to directly add intellectual value to the library.

As a trusted source of high-quality Science, Technology, Engineering, and Mathematics (STEM) resources, NSDL faced some clear challenges in building on the expertise of the user community. Resources in the NSDL are carefully selected, and it was not possible for us to simply throw open the doors for arbitrary community contributions, as organizations such as Flickr, MySpace, and Wikipedia have done. Indeed, the focus is much more on allowing the community to improve the usability of the resources already in the library, by adding context, than it is on adding new resources, although both are possible.

NSDL 2.0 also embraces the Web 2.0 view of *the web as platform*. All the capabilities of the library: adding metadata, resources and relationships; obtaining disseminations of library content and context; and making use of the search, browse, and archiving functions are implemented as REST-based web services. Organizations outside of NSDL CI (e.g. DLESE, Instructional Architect) are already beginning to build new tools and capabilities on this platform.

Finally, NSDL 2.0, and indeed the entire NSDL effort, works to create an *architecture of participation.* On the technical side, our open source software, web services platform, and multiple models for contribution, collaboration, and participation all work together to encourage individuals and organizations to contribute to the library at multiple levels. On the organizational side, the NSDL comprises many different groups, institutions, and individual participants. [something about how these groups will be engaged —see "Integrated CI Production-level Content Plan" NSDL CI supports groups that wish to use the NSDL web services, runs workshops for teachers and others on how to use NSDL and the Expert Voices blogging tool, and engages in a range of other outreach efforts focused on encouraging participation in the NSDL.

3.4 A General Model for Collaborative Context Creation

As of early 2007, there are a large number of very successful tools for community formation, discussion, contribution, collaboration, and sharing. These range from very general purpose tools such as wikis, blogs, and bookmarking/tagging systems, to more specialized tools: LibraryThing for sharing personal library catalogs; Moodle for course management in higher education; Flickr for sharing photos; and YouTube for sharing videos.

The NSDL CI development team is small, and web applications change very quickly. Rather than trying to create new NSDL-

specific tools for contribution, collaboration, and context creation, we have chosen to build on major open-source instances of existing, successful Web 2.0 tools. Typically, this involves creating extensions for each tool with the following set of capabilities:

1. Search/browse/view: Within the tool, it must be possible to easily search, browse, and/or view the NSDL for appropriate existing resources relevant to the topic at hand.
2. Resource reference: Using the unique NSDL resource identifier, a reference to the resource in the library is included in the content being created by the tool.
3. New resource specification: Frequently, the tool user will wish to either create a new resource within the tool (e.g. a lesson plan) or to specify/recommend that a particular external resource (typically a URL) should be included in the library.
4. Metadata provision: Basic and optional metadata can be provided for both existing referenced resources and newly created resources.
5. Capturing structure and relationships: By citing or creating NSDL resources within the tool, the user will create a web of interrelationships among those resources and between the resources and any new content or metadata. This needs to be captured and reflected back into the NDR for the benefit of the entire community.
6. Publication to the NDR: Finally, the information created by the user must be published back to the NDR. This may require authorized access and editorial approval.

We've initially applied this model to two different general purpose web tools. We have implemented extensions to WordPress Multiuser to create the ExpertVoices blogging tool, and we are currently designing and implementing these extensions for MediaWiki to create OurNSDL. We discuss the specific applications and challenges for each of these tools in sections 4 and 5 below, discussing how the structure of information in the tools is reflected in the NSDL itself.

Currently, one outside group, the Instructional Architect team at Utah State[8], is looking at applying this model to their lesson plan application. We plan to explore other collaborative applications that are suitable for this general model, and we are interested in working with any group that has an application that they would be interested in integrating with the library.

3.5 Trust and Quality

When proposing an open model of community contribution, the issues of trust and quality immediately arise. Wikipedia, for example, has one of the most open contribution models on the web, and issues surrounding its quality and reliability have been raised repeatedly[4]. The issue of quality is fundamental for any library, and particularly so for a library such as the NSDL that serves younger students and their teachers as part of its audience.

Most collaborative Web 2.0 applications, such as Wikipedia, Flickr, and Slashdot, create systems of community rating, filtering, and reputation management in an effort to present their users with a high-quality view of the community provided information. The downside of this approach is that there is almost guaranteed to be some level of "bad" information presented to users, whether provided maliciously or not. For relatively sophisticated users, the benefits may clearly outweigh the risks, but this is not the case for a large subset of NSDL users.

One alternative is a strict authority model for approving community contributions. This is the model used by traditional encyclopedias, and it is also the model used on the web by the Encyclopedia of Earth[9]. Another alternative is to provide multiple views of the library, with a trusted view that has undergone some level of community vetting and a "raw" view that includes all contributions.

For NSDL, we were concerned both that the effort is too large and diverse to support a strict authority model, and that the multiple views might still cause confusion for our less-sophisticated users over the meaning of the NSDL brand. Our current trust model is based on having new contributions approved by one of a potentially large community of authorized reviewers. In the future, we plan to move to a more sophisticated model with an explicit graph of transitive authorization, somewhat similar to the web of trust key signing model used by PGP[ref???]. In the event of a breach of the trust mechanism (e.g. due to stolen credentials), the graph could be pruned to eliminate the compromised user and any users that they had authorized.

For some applications, by focusing on creating context rather than on arbitrary content contribution, the issue of guaranteeing quality issue becomes simpler. If we simple capture the association of resources together in a lesson plan, or suggestions of appropriate grade level and audience for a resource, it is still possible for a malicious or uninformed user to degrade the way the library suggests appropriate resources, but the fundamental scientific information will not be compromised.

We believe that we have chosen an appropriate starting point in the effort to balance quality, trust, and community contribution, but we anticipate that this will be a major area of ongoing discussion, review, and probably change.

4. EXPERT VOICES: BLOGGING IN NSDL

Expert Voices was developed as a collaborative tool to increase community contributions to the library; to relate library resources to real-world science events; and to provide context for science resources in the library. Expert Voices provides the infrastructure for engaging teachers, scientists, librarians, and students in conversations about STEM topics. As an integrated component of the NSDL, Expert Voices makes it easy for users to find content from the library, and it allows them to exchange ideas and point each other to useful online materials.

The system is built using a standard, open-source blogging system (WordPress MultiUser[10]) and supports blogging standards, themes, templates, and plug-in functionality. In addition to the inherent ability to add and edit blog content, contributors can also embed links to existing NSDL resources and add new resources to the NSDL via custom plug-ins. This provides a wider domain of content and exposes richer resource context by capturing the relationships between blog contents and referenced resources, and

[8] http://ia.usu.edu

[9] http://www.eoearth.org/

[10] http://mu.wordpress.org/

by adding simple structured metadata. The plug-ins take advantage of publicly available NSDL REST-based web services: the NSDL search service and the NDR API

4.1 A Conversation about Science

There are a number of potential scenarios for using Expert Voices blogs. Existing blogs primarily follow the discovery team, classroom, or community models. Discovery teams are about creating educational products that will become part of the NSDL for others to use, and they focus on the exchange of ideas among educators and content experts about a specific or broad topic. In the classroom model, teachers can use blogs to create lesson plans for their students, and students can use them for writing and collaboration [15]. In the library-building community blogs, users can present current STEM news and events and promote educational outreach.

The discovery team model provides a low barrier opportunity for time-constrained teachers to connect to scientists. Scientists can share their knowledge and zeal for their profession using online communication tools. Blogs provide an opportunity for scientists to debate results of studies or events in real time and to organize information and steer discussions.

"Few scientists have caught on to the Internet's power of posting, commenting, and debating – where are the rest?"[16]

The process begins when an NSDL outreach staff member creates a blog about the upcoming hurricane season and enlists bloggers to form a multidisciplinary team consisting of a National Weather Service hurricane expert, an earth science teacher, and a school media specialist familiar with NSDL. The team members are granted proper authorization to post and to add resources to the NSDL and oriented to the Expert Voices system. After initial introductions and discussion, the hurricane expert contributes a post that announces, "Hurricane Gertrude is heading for Ft.Lauderdale; 15 foot storm surge expected; undergoing eyewall replacement cycle". The media specialist searches for and inserts NSDL resource links of the Hurricane Hunters site, the latest satellite photos, and the USGS flooding and flood plain web page. The teacher facilitates the discussion providing pedagogical expertise and connects the information to relevant education standards. The students are directed to read the blog and given permission to comment or pose questions to the expert. Everyone involved has the opportunity to engage in real-time, real-world applications of science lessons from high quality multi-faceted sources.

A link to the hurricane blog is added as a resource to the NSDL and any posts with substance are also added. A search for the term "hurricane" performed on the NSDL web site will find the hurricane blog and posts and also provide information about the related referenced resources presented in the blog posts. These can then be reused by others in other learning objects or lessons.

4.2 The User Experience

The design and development of Expert Voices has been and continues to be an iterative process involving user testing, user surveys, content analysis, and web statistics analysis. The user testing includes representatives from our intended audience base: teachers, faculty, librarians, library builders, students, and informal learners. Interface and work flow challenges deal with both the blogging functionality and library interactions.

There are many individual blogs within Expert Voices about different topics, designed for various audiences. The home page provides a gateway to pull the user in with an overview of Expert Voices' *blogosphere*. There is a section displaying blog titles by audience, another for posts by topic or category, and a section displaying the more recent posts in Expert Voices.

Early user feedback indicates the gateway is too "busy" and creates confusion for new users. Other display options are being tested, including a treemap of the blog activity by audience for a quick overview of what's happening, and an area for the NSDL content editors to highlight interesting conversations and to sieve the content for casual readers. Other efforts are underway to make the gateway simpler, yet still provide user's with a view of the many blog options.

Experienced Expert Voices users find blogs that interest them and frequently use their favorite news reader to point to specific blog RSS newsfeeds. Site-wide audience-based RSS newsfeeds were also developed to disseminate a list of blogs and their links to the http://nsdl.org audience portals, NSDL Pathway projects, and groups like National Science Teachers Association, eSchoolNews, National Council of Teachers of Mathematics, etc. Users have the ability to categorize or tag their posts so they show up appropriately on the gateway and in the library search results.

Because the system is built on popular blogging software, the basic functionality is familiar to the average blog user. But confusion still exists about who can comment or post and what the differences are between the two. A "Help" blog was created that includes information about the different blogging scenarios and about using blogs in the classroom. It also includes an FAQ and tutorials for readers, contributors, and administrators of the blogs.

The Expert Voices custom plug-ins for interacting with the library are designed to be as simple as possible to encourage discovery and contribution of resources. The search popup plug-in allows users to find resources and formats the links for inserting into the blog content. The contribution popup plug-in provides forms for simple metadata submission and creates all the relationships in the library behind the scenes. Not all blogs will have the ability to contribute to the library and only authorized users can use this functionality.

5. OurNSDL: INTEGRATING WIKIS IN NSDL

OurNSDL is the second major collaborative tool to be integrated into the NSDL. Currently in the design phase, OurNSDL builds on wiki technology to allow communities of users to create, annotate, and organize NSDL resources. Following the general model described in section 3.4, a pre-existing, open-source software package, MediaWiki[11], is being augmented with plug-ins and extensions to fully integrate the application with the NSDL data repository. These tools are designed to be used by authorized NSDL partners and projects working with a target audience of undergraduate and graduate students, educators, and researchers. Partners can incorporate the tools into their projects' wiki environment or use the services on the OurNSDL wiki web site.

The core software for OurNSDL is the same used for Wikipedia[12], and so it provides the familiar functionality of collaborative authoring using a simplified markup language, hyperlinks, and

[11] http://www.mediawiki.org

[12] http://en.wikipedia.org

user categories to create and modify wiki pages[18, 20]. In addition to the default wiki functionality, the OurNSDL tools provide the ability to add newly created wiki pages to the NSDL data repository as resources with simple structured metadata. NSDL resources or a subset of resources can be reflected into the wiki engine allowing them to be discovered, referenced, or annotated.

Users or groups can also use the wiki pages to collect and organize NSDL resources for information dissemination and/or teaching purposes. The editor can reference resources from inside or outside of the NSDL (other wikis or web pages). A wiki page with lists of resources can be added as a stand-alone resource.

Soft Matter Wiki[13] for its community to share information pertinent to soft matter and nanomaterials. MatDL is "a consortium of organizations building an information infrastructure and assuming stewardship of significant content and services to support the integration of education and research in materials science."[14] Authorized MatDL users create wiki pages and will be able to add them as new resources with metadata in the NSDL using the custom NSDL MediaWiki extensions. The non-wiki-based repository resources are displayed as read-only wiki pages, and are available for comment, linking and collecting on new wiki pages. Once part of the repository, the new resources become discoverable on the nsdl.org website and search interface.

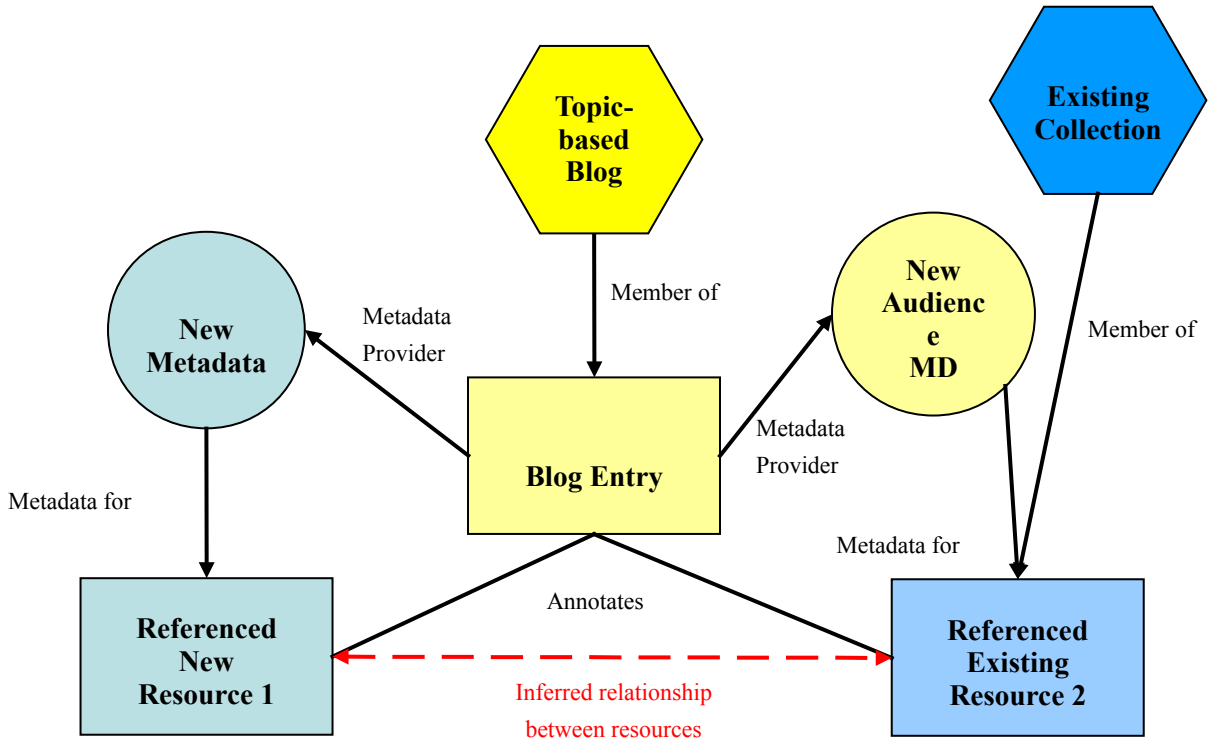

Figure 1 - Creating a Blog Entry in the NDR

The repository stores the referenced resources as members of an aggregation creating a relationship that is exposed in the library's public interface for others to discover and repurpose. If the referenced resources are not in the library, the editor can add them using OurNSDL tools.

Unlike Wikipedia, OurNSDL needs to more closely manage user and group access for quality control and to integrate with the NSDL sign-on. Skeptics of Wikipedia question the lack of a formal content inclusion and review process[4]. OurNSDL falls somewhere between the open Wikipedia model and a closed model, hopefully creating a dynamic and useful digital libray. A community of approved contributors (e.g. teachers, librarians, scientists) will be granted access on the OurNSDL wiki and select authorized users will be able to contribute resources to the NSDL data repository.

An early adopter of the OurNSDL toolset will be the NSDL Materials Digital Library (MatDL) Pathway, which has created a

6. FUTURE WORK

[13] http://matdl.org/matdlwiki

[14] From http://matdl.org/matdlwiki/index.php/NSDL_Materials_Digital_Library_Soft_Matter_Wiki:About

6.1 MyNSDL: Bookmarks, Tags, and Recommendations

Based on Connotea open-source folksonomic tagging/bookmarking system

Tags and bookmarking structure are reflected back into the NDR

Authorized users can “automatically” recommend new NSDL resources simply by tagging them

Gives user a personal view of NSDL resources

6.2 Other Tools for Collaborative Context Creation

Instructional Architect

Virtual Lab Notebook

Moodle

6.3 Community Formation, Quality and Trust

6.4 Using Context: Navigation and Visualization

7. CONCLUSIONS

8. ACKNOWLEDGMENTS

This material is based upon work supported by the National Science Foundation under Grants No. 0227648, 0227656, and 0227888. The authors acknowledge the efforts and support of the entire NSDL Core Integration team. Particular thanks go to Aaron Birkland, James Blake, Carl Lagoze, and Carol Minton Morris for their contributions and suggestions to this paper and the research described herein.

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