

# Enhancing Interoperability of Collections and Services

Final Report, December 2004<sup>1</sup>

NSF Award DUE-0127580

## 1. Summary

Evolving from NEEDS (the National Engineering Education Delivery System), the SMETE Open Federation (SOF) formed as an e-learning partnership that offers a comprehensive collection of high quality STEM (science, technology, engineering & mathematics)<sup>2</sup> digital learning resources<sup>3</sup> and value-added services at [www.smete.org](http://www.smete.org). We allow authors and other submitters to *add* learning resources ‘anywhere, ‘anytime’ through our Web-based cataloging system. We review each learning object, consistent with library cataloging standards, to check for critical metadata fields and operation on one of the intended platforms. We use reviews/comments as quality feedback on highly used selected items. To date (June 2004) we have approximately 8,000 learning objects and 3,000 registered users. We support the National Science, Technology, Engineering and Mathematics Education Digital Library (NSDL) program by engaging in collaborative research, deployment and services related to enhanced harvesting, federated search, interoperability, scalability, usability, and personalization. We have developed extensive software environments and toolkits. In the past year we have developed a service that permits any collection or service to search our extensive repository of learning objects at [www.smete.org](http://www.smete.org). The service, based on the emerging SOAP specification utilizes standards-based methods to query the repository and receive item-level metadata of learning objects matching the query. We have also created a personalization service called *My Portfolio* that allows users to create a user profile and enables them to save found learning resources to their personal workspace. We also provide a recommender service using hybrid collaborative filtering, usage logs, and profile information. A strength of the SMETE.ORG approach has been to transfer cutting-edge research into the features and services it provides as summarized below:

- *Search and Browse* Search features include simple keyword based search and a fielded “Find” page including pedagogy, audience-level and collection. “Browse” features include selection from a number of controlled vocabularies. Search and Browse results provide key details on the resources (cost, reviews, collection, etc.). [“Find it”]
- *Cataloging* learning object metadata to describe educational resources in a rich fashion, appropriate to use and need. Two levels of cataloging are available, a simple “recommendation” form and a full, web-based cataloging system available for registered users. Cataloging is based on the rich description available through the IEEE Learning Object Metadata Standard<sup>4</sup>; harvest via normalized metadata is supported. [“Describe it”]
- *User Comments and Reviews*. *User comments* enable registered community members to share how they have used a particular resource. *Reviews* provide expert commentary on a resource.

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<sup>1</sup> This is a collaborative grant with Dr. Su-Shing Chen at the University of Florida with a subcontract to Dr. Ed Fox at the Virginia Tech University. Dr. Chen’s final report will be submitted separately.

<sup>2</sup> Recently NSF switched the “T” and “M” in the ordering of the disciplines so that SMETE stood for SMET Education.

<sup>3</sup> By collection: NEEDS (locally cataloged)=1,787, Computer Science Teaching Center (harvest)=70, Digital Library for Earth System Education (harvest)=1,904, LearningOnline Network with CAPA (harvest)=3,169, Michigan Teacher Network (harvest of high-level subjects)=85, Nat’l Library of Virtual Manipulatives for Interactive Math (harvest)=154, Stanford University Paper Bike Project (locally cataloged)=284 and test collections (sample harvests/local catalog or re-catalog)=120.

<sup>4</sup> Project staff helped author the IEEE 1484.12.1-2002 Standard for Learning Object Metadata.

NEEDS is collaborating with MERLOT<sup>5</sup> on peer reviews and conducts the *Premier Award for Excellence in Engineering Education* competition recognizing outstanding *Premier Courseware*. [“How do I use it?”]

- *My Workspace/Portfolio* for registered community members. *My Workspace* provides access to personalized recommendations. *My Portfolio* enables members to save resources for later use. [“Save and reuse it”]
- *Technology Service Provider*. SMETE.ORG is now positioned to provide technology services to the NSDL program and currently provides digital library services for the Exploratorium Online<sup>6</sup> and the Digital Chemistry Library collections, as well as the NSDL Collaboration Finder<sup>7</sup>. In addition SMETE.ORG consulted on the startup of the BioSci Ed Net ([www.bioscienet.org](http://www.bioscienet.org)), Eisenhower National Clearinghouse’s newer collections ([www.encedl.org](http://www.encedl.org)), MathDL ([www.mathdl.org](http://www.mathdl.org)) and many others. [“Help Others”]
- *Interoperability* with the *harvested* and/or *federated* collections spanning STEM disciplines, NEEDS and NSDL. [“Get it” and “Provide it”]
- *Recommender systems* to recommend learning resources based on resource usage and/or user profiles. [“Recommend it”]
- Development of *metathesauri* that formalize relations among knowledge structures. [“Relate it”]

More specific details associated with our progress to date in developing technologies to enable protocol and transactional interoperability between the collections and services in the NSDL program follows.

## 2. Interoperability: Harvesting and Federated Search

Interoperability enables collections to extend their reach by increasing the opportunity for discovery of resources and providing additional resources related to its local collection. SMETE.ORG developed and implements federated search with multiple collections using two approaches: harvesting and agent-based federation. Both approaches recognize the contributions and intellectual property<sup>8</sup> of partner collections and have developed in close collaboration with the partner. These low barrier-to-entry mechanisms enable the SMETE.ORG approach to meet or exceed the metadata requirements of NSDL Policy Committee and Core Integration team implementation (by using richer metadata element sets) and provide agreement-based access to metadata.

The harvesting approach relies upon the Open Archive Initiative-Protocol for Metadata Harvesting and custom gateways to build a centralized metadata repository from partners, as well as provide access to locally cataloged collections. In some cases (e.g., LON-CAPA and the Michigan Teacher Network), IEEE Learning Object Metadata-based local application profiles is

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<sup>5</sup> MERLOT—the Multimedia Educational Resource for Learning and Online Teaching is an international cooperative, based in the U.S., for high-quality online resources to improve learning and teaching within higher education. MERLOT conducts discipline-based peer review in fourteen areas including engineering in partnership with NEEDS.

<sup>6</sup> Exploratorium, Educator Digital Assets, <http://www.exploratorium.edu/educate/edam/>

<sup>7</sup> The NSDL Collaboration finder is at [www.SMETE.ORG/nsdl/](http://www.SMETE.ORG/nsdl/) and enables NSDL projects to share their activities to enable program-wide collaboration.

<sup>8</sup> SMETE.ORG policy states that it will not retransmit harvested metadata, without permission, in accordance with agreements with partners.

transformed to normalized application profiles using tools developed by SMETE.ORG as it is harvested.

The second approach federates collections by deploying agents to perform searches of a partner's metadata, report back to the portal and present aggregated search results. SMETE.ORG developed a federated search server-client specification to enable others to remotely query SMETE.ORG, and uses this as a basis for how it interoperates with other collections. A partner collection implements a web-services framework to describe their metadata format, query and response mechanisms supported and other key features supported by their client via a Web Service Definition Language (WSDL) file. SMETE.ORG is then able to query the partner collection and aggregate its results with simultaneous queries of other collections (returned via a SOAP transport layer)<sup>9</sup>. In return the partner collection is able to query the SMETE.ORG catalog in a similar fashion. Several other digital libraries have taken advantage of our API for interoperability (see email exchange in Appendix). The service is closely modeled on the Lucene query syntax, the Open Archives Initiative Protocol for Metadata Harvesting structure for the response, and the Google Web API for the request envelope, thus reducing the amount of new code collections and services must write to utilize the service if they desire to develop their own client applications. We also provide ready-to-implement clients in both Perl script and Java packages for our partners for fast prototyping of federated search service with us. SMETE.ORG and MERLOT have implemented this specification to enable cross-federated search between the NEEDS and MERLOT collections.<sup>10</sup>

Both harvesting and agent-based federation are challenging because each collection provider uses a custom metadata format, along with particular program and storage resources, to store metadata for materials in their collection. SMETE.ORG's interoperability efforts have benefitted greatly from the development of a metadata cross-walk tool for use with arbitrary data sources that converts metadata stored in arbitrary formats and in different access containers to representations of IEEE Learning Object Metadata or Dublin Core XML bindings.

SMETE.ORG has also implemented tools to enable advanced interoperability of NSDL collections. SMETE is working with LON-CAPA ([www.lon-capa.org](http://www.lon-capa.org)) to integrate SMETE.ORG's personalization service with their learning management system, and Utah State University to send a user's collection of digital learning resources in *My Workspace* to the Instructional Architect ([ia.usu.edu](http://ia.usu.edu)).

The following collections are now searchable from the [www.SMETE.ORG](http://www.SMETE.ORG) portal using our various forms of interoperability:

1. Center for Highly Interactive Computing in Education: 3 learning objects
2. Computer Science Teaching Center: 70 learning objects
3. DLESE: 1,904 learning objects
4. Eisenhower National Clearinghouse: 31 learning objects

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<sup>9</sup> Paepcke, A., R. Brandriff, G. Janee, G. Larson, B. Ludaeschre, S. Melnik and S. Raghavan, Search Middleware and the Simple Digital Library Interoperability Protocol, *D-Lib Magazine*, 6(3), March 2000.

<sup>10</sup> For more details see [www.SMETE.ORG:80/smete/?path=/public/soap/index.jhtml&fedsearch.merlot.org/main/search.jsp](http://www.SMETE.ORG:80/smete/?path=/public/soap/index.jhtml&fedsearch.merlot.org/main/search.jsp).

5. LearningOnline Network with CAPA: 3,168 learning objects
6. Michigan Teacher Network: 85 learning objects
7. Math Forum: 20 learning objects
8. Mathematics Association of America: 10 learning objects
9. National Library of Virtual Manipulatives for Interactive Math: 154 learning objects
10. NEEDS (National Engineering Education Delivery System): 1,788 learning objects
11. Stanford Paper Bike Project: 377 learning objects

SMETE.ORG participated with the Core Integration team and the Digital Library for Earth System Education (DLESE) in the deployment and testing of the DLESE OAI tool. We have made the National Engineering Education Delivery System (NEEDS) Premier Award Winners from 1997-2003 available at <http://www.SMETE.ORG/oai/provider?verb=Identify>.

### **3. User Registration and User Profiles**

We developed and instituted a user registration system and allowed registered users to develop user profiles. The NEEDS/ SMETE.ORG system currently has approximately 3,000 registered users.

We created a personalization service called *My Portfolio* at the [www.SMETE.ORG](http://www.SMETE.ORG) portal, which allows users to create a user profile and enables them to save found learning resources to their personal workspace. In addition, based on the resources the user has downloaded, the system also provides recommendations to similar resources and people with similar likes [1]. We developed the metadata for the user profile in collaboration with Utah State University and iLumina.

We have two ongoing projects that extend our personalization service to demonstrate a mechanism by which a portal can pass through user authentication information securely to a collection or service to grant registered and authenticated users access to the collection or service. We are currently working with NSDL program members LON-CAPA, to integrate our personalization service with their learning management system, and Utah State University to send a user's collection of learning objects in *My Workspace* to the Instructional Architect.

### **4. Recommender System**

SMETE.ORG developed recommender systems to address the contextual nature of user information needs by automatically recommending relevant resources to registered users through algorithms that learn from their past search sessions. Personalized recommendations are generated by applying Latent Interest Analysis (LIA), a new technique that combines the computational text analysis tool of Latent Semantic Analysis (LSA) with web usage tracking and analyses. The recommender systems are interspersed through SMETE.ORG (on search results, individual digital learning resource descriptions and through *My Workspace*). The recommender systems provide three different types of recommendation services: item-to-item recommendations based on the usage data of a resource, user interest recommendations based on usage data of the user's previous searches and user profile data, and like-minded user recommendations based on either usage data or user profile data. The LIA-based recommender

system consists of five modules: *Web usage tracking* (collects user behavior/activities in real time; stores all data directly into a database), *Web usage analysis* (processes usage data offline to generate static user interest info), *Content analysis* (generates term/document model in LSA space offline), *User information needs modeling* (with recent search information, builds user information needs model in LSA space, and adjust using user's static interest vector) and *Recommendation generation* (determines recommended learning resources by semantic similarities of user information needs vector and learning resource vector).

## **5. Metathesaurus Development**


Through our targeted research grant (NSF DUE-0121743), Metathesaurus technology is being developed to formalize relations among structures of knowledge (expressed as linked thesaurus concepts) from many viewpoints and will enable cross- and multi-disciplinary browsing and searching. A metathesaurus maintains a set of key concepts of the domain, semantic relationships between concepts such as synonyms, hyponyms (a word that is more specific than a given word), and also mappings from various source thesauri to the key concepts. Relatively few of these have been constructed; those that have been built were generally hand-coded at great expense. The process has typically been to figuratively overlap existing structures and "pin" them together at common points. SMETE.ORG also developed a machine-learning framework from which to build metathesauri; preliminary results have been incorporated in NEEDS and SMETE.ORG .

## **6. Evaluation**

The interoperability API has been highly successful and users within NSDL (e.g., Merlot), as well as those not associated with the NSDL program are performing federated search from their own educational digital libraries. In order to quantify the broader impact of SMETE.ORG and how users perceive it, we developed and instituted a transaction-based system to track queries (simple search, advance search, and federated search), query results, downloads, time spend on accessing a resource related pages, user trails including entry pages and exit URLs, etc. Our usage metrics extend the current digital library logging standard provided by the Educational Impact and Evaluation Standing Committee (EIESC). We also developed a web-based usage analysis tool to automatically extract knowledge from the tracking system. The goal is to provide real time customized reports for the SMETE team and lead authors to help improve the design of the system as well as providing relevant usage statistic to the authors on his/her learning resources in our system. We also coupled this *extended usage tracking* with a *user registration system* (below) to develop a recommender system that provides users with recommendations based upon their past action and the collective use of SMETE/NEEDS by the community at large.

**Learning Resource: Disk Drive Case Study**

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Please tell us about your experience with our resource recommender system.

The recommendation was helpful

The recommendation was not helpful

**Title:** Disk Drive Case Study

**Authors:** Alice Agogino

**Publishers:** University of California at Berkeley

**Subject:** Engineering (NEEDS)::Mechanical engineering::Mechatronics::Mechatronics -- Computer-assisted instruction , Engineering (NEEDS)::Electrical & computer engineering::Computer engineering::Computer storage devices -- History::Disk drives -- History , Engineering (NEEDS)::Electrical & computer engineering , Engineering (NEEDS)::Electrical & computer engineering::Electromechanical devices , Engineering (NEEDS)::Electrical & computer engineering::Electric machines::Electric drills -- Design::Stepping motors -- Design and construction , Engineering (NEEDS)::Electrical & computer engineering::Computer engineering::Computer storage devices -- History

**Description:** A disk drive is a good example of a mechatronic product. The main topics covered in this case study are overall view of the disk drive industry, historical perspective, indication of future trends, market and financial aspects of the industry, principles behind magnetic recording, disk drive design specifications, modeling of the disk drive for mathematical analysis and important testing and experimental techniques.

**URL:** [http://bits.me.berkeley.edu/cw/00/00/60/1/Disk\\_Drive\\_Demo.sea.hqx](http://bits.me.berkeley.edu/cw/00/00/60/1/Disk_Drive_Demo.sea.hqx)

**Possible Use:** Case Study

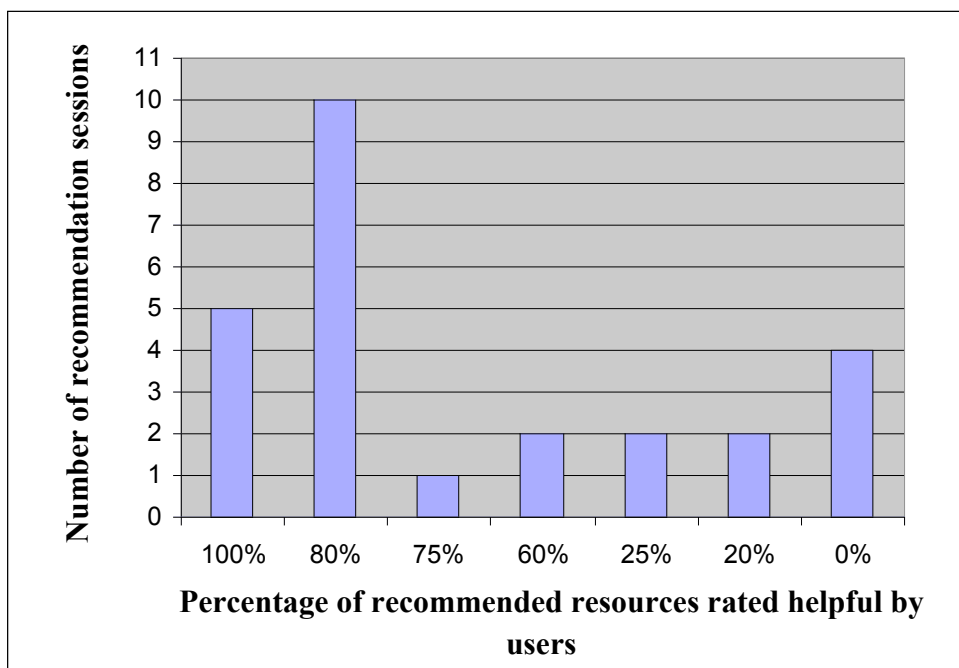
**Audience/Grade:**

**Platform/Format:** Macintosh

**Cost:** Freeware

**Figure 1: User evaluation interface.**

A combination of qualitative observations and an on-line survey were used to ascertain the usefulness of the *user interest recommendation* to actual users. A snapshot of the on-line evaluation page from SMETE/NEEDS is illustrated in Figure 1. Evaluators were asked to rate the recommended learning recourses in the *My Interests* page based on whether they thought those recommended resources were helpful or not helpful. The evaluators were either professors or graduate students who were users of the SMETE/NEEDS educational digital library. The evaluation results are shown in Figure 2. There were a total of 26 recommendation sessions evaluated by users. More than 80% of the recommended resources in 15 sessions were regarded helpful while less than 20% of the recommended resources in 6 sessions were deemed not helpful. For the remaining 5 recommendation sessions, helpful resources vary from 25% to 75%. The average percentage of helpful recommended learning resources per recommendation session is 61%. Similar results can be found in Sinha (2001) study on comparing recommendations made by online recommender systems. The average percentage of good recommendations for books by online recommender systems (Amazon, Sleeper, RatingZone) is 46%. Amazon performed the best among the three online recommender systems with 60% of good recommendations rated by users. This shows that the quality of our recommender system is comparable to commercial online systems and effective for users targeting STEM educational learning objects.



**Figure 2: User evaluation of recommended resources.**

Dr. Flora McMartin, the former Chair for the NSDL Evaluation Committee and former co-Chair of the NSDL Policy Committee, drafted an evaluation study of NSDL collections and portals, which we participated in. We provided the EIESC with information regarding the subject areas of our learning resources, the types of learning resources, the number of registered users, the age and grade range of the intended audience for our resources, and other statistics for an initial evaluation study of the NSDL program. We continue to work with the EIESC in support of the overall evaluation program of the NSDL.

Although specified in the work plan of the grant, during the Summer of 2004 we launched a program for the summative evaluation of the SMETE.ORG site and the services it provides. Our questionnaire evaluates the effectiveness of interoperating with the SMETE digital library through partners already successfully interoperating with the site and from any who have expressed a desire to do so. We are eliciting feedback concerning the effectiveness of the recommender system, the short cataloging and full cataloging features, the suggestions provided by the metathesaurus and the usage of the *My Workspace* feature.

The evaluation is being conducted through questionnaires sent to lead users of the site and phone interviews and focus groups to develop recommendations for future work. The lead users will also be asked to participate in the peer review system for the resources by providing reviews of existing and newly submitted resources. The studies will also be used to provide feedback on the usability of the site as a whole. The results of this summative evaluation are expected to be completed by April 2005.

## 7. Publications and Products from NSF Grant DUE-0127580

With partial funding from this grant, the following publications, outreach presentations and web products were completed.

### Journal Publication

1. Song, S., Dong, A. & Agogino, A.M. (2002). Modeling Information Needs in Engineering Databases Using Tacit Knowledge. *Journal of Computing and Information Science in Engineering*, 2, No. 3, Sept. 2002, pp. 199-207.

### Conference Proceedings

2. Dong, A. and A.M. Agogino, "Designing an Untethered Educational Digital Library", Proceedings of the IEEE International Workshop on Wireless and Mobile Technologies in Education (WMTE 2004; <http://ltf.ieee.org/wmte2004/>, March 23-25, 2004).
3. Dong, A., E. Fixler and A.M. Agogino, "A Case Study of Policy Decisions for Federated Search Across Digital Libraries," *Proceedings of ICDL 2004* (International Conference on Digital Libraries).
4. McMartin, F. And Y. Terada, "Digital Library Services for Authors of Learning Materials", *Proceedings of the Second ACM/IEEE Joint Conference on Digital Libraries*, OR, USA, July 14-16 2002, pp. 117-118.
5. Muramatsu, B., Giersch, S., McMartin, F., Weimar, S. & Klotz, G. "If You Build It, Will They Come?" Lessons Learned from the Workshop on Participant Interaction in Digital Libraries. *Proceedings of JCDL 2004*, Tucson, AZ. June 7-11, 2004.
6. Teng, X., B. Muramatsu, J. Tront, F. McMartin and A. M. Agogino, "Implementation of Quality Evaluation for Web-based Courses and Digital Learning Resources," *Proceedings of the 3<sup>rd</sup> International Conference on Web-based Learning* (Aug. 8-11, 2004, Tsinghua University, Beijing, China). <http://www.icwl2004.org/>
7. Wu, J. and A. M. Agogino, Automating Keyphrase Building with Multi-Objective Genetic Algorithms," *Proceedings of the Hawaii International Conference on System Science*, HICSS, 2004.

### Technical Reports

8. Dong, A., E. Fixler, A.M. Agogino, M.J. Koning-Bastiaan, and S. Shamseldin, "A Web Services Approach to Federated Search Across Digital Libraries". Working Paper # 03-0103-3, 2003. Berkeley Expert Systems Technology Laboratory, 6102 Etcheverry Hall, UC Berkeley, Berkeley, CA 94720-1740.
9. Giersch, S., G. Klotz, E., F. McMartin, B. Muramatsu, K.A. Renninger, W. Shumar, & S. Weimar, NSF/NSDL Workshop: Participant Interaction in Digital Libraries Workshop Report. February 6-8, 2004. Retrieved from [http://comm.nsdsl.org/docman/view.php/97/459/pidl\\_report.pdf](http://comm.nsdsl.org/docman/view.php/97/459/pidl_report.pdf) on May 27, 2004.
10. Wu, J., E. Fixler, and A.M. Agogino, "Translating Between Native Java Objects and LOM: A Tools to Assist Digital Libraries Exchange Information." Working Paper # 03-0203-3, 2003. Berkeley Expert Systems Technology Laboratory, 6102 Etcheverry Hall, UC Berkeley, Berkeley, CA 94720-1740.

## Outreach Presentations

11. Agogino, A.M. (for L. Zia, 2001). "Successful Partnering" at the "Forging Library Partnerships in the Networked Age," Clark Kerr Campus, UC Berkeley, Nov. 2, 2001.
12. Agogino, A.M., "Bringing the Educational Experience of NEEDS and SMETE.ORG to NSDL", AAAS Annual Meeting: Science as a Way of Life, (13-18, Feb. 2003, Denver, CO), CD ROM.
13. Agogino, A.M., "Ubiquitous Wireless Infrastructure to Support Mobile Learning," HP/CITRIS 2004 Workshop on Planetary-Scale Applications, Wed., May 26, UC Berkeley.
14. Dong, A. (2001). Enhancing Interoperability for the National SMETE Digital Library Program, UC Berkeley Digital Library Seminar, October 15, 2001.
15. Dong, A. and Agogino, A. (2002). Who's Out There? Building Community through Recommendations, MERLOT International Conference 2002, Atlanta, GA.
16. Dong, A., Koning-Bastiaan, M. & Muramatsu, B. (2002). Implementing Federated Search Across Collections, MERLOT International Conference 2002, Atlanta, GA.
17. Dong, A. (2002). Planning to Make the Best Use of the National Science Digital Library, Project Kaleidoscope Workshop on The World Wide Web: Strengthening the Undergraduate Learning Environment, United States Air Force Academy, Colorado Springs, Colorado, February 8 - 10, 2002.
18. Mardis, M. & Muramatsu, B. (2003). The Collaboration Finder, poster presented at the NSDL All Projects Meeting, Washington, DC, October 12-14, 2003.
19. McMartin, F., Muramatsu, B. and Tront, J.G. (2001, Oct.) Introduction to Evaluating, Selecting and Using Computer Enhanced Learning Technologies and Courseware in Engineering Education. Workshop at the 2001 Frontiers in Education Conference, Reno, NV.
20. Muramatsu, B. & Hanley, G.L. (Feb. 2002). Digital Libraries: A Vehicle For Transforming Education in the Sciences, Mathematics, Engineering And Technology? Presentation at the TechEd 2002 Conference, Long Beach, CA.
21. Muramatsu, B., Tront, J.G., & Bayard, J.P. (2002, September). Selecting E-Learning Materials for Adoption and Adaptation in STEM. Workshop at the 2002 MERLOT International Conference, Atlanta, GA.
22. Muramatsu, B. (Moderator). (2003, October). Collaboration in NSDL: Ad Hoc Collaboration, roundtable at the NSDL All Projects Meeting, Washington, DC, October 12-14, 2003.
23. Muramatsu, B. (2003, January) NSDL Collaboration Finder, presented at MERLOT Mid-Year Meeting, New Orleans, LA, January 2003.
24. Tront, J.G. and Muramatsu, B. (2002, June). Adopting and Adapting E-Learning Materials. Workshop at the Share the Future III Conference, Gainesville, FL.
25. Tront, J.G. and Muramatsu, B. (2002, June). A Community for Developing High-Quality Technology-based Courseware. Workshop at the 2002 American Society for Engineering Education Annual Conference and Exposition, Montreal, CA.

## **Websites and Web Reports**

26. SMETE digital library at [www.smete.org](http://www.smete.org). The SMETE digital library is the gateway to a comprehensive collection of science, mathematics, engineering and technology (SMET) education content and services to learners, educators, and academic policy-makers.

## **MS Theses/Reports**

27. Hill, Andrew, "Creating Online Faculty Collaboration to Develop Engineering Education Computer Learning Materials," MS Plan II, 2001/2002. Part of this work includes user studies and assessments of educational digital libraries in STEM disciplines.

## **PhD Dissertations**

28. Song, Shuang, "Shared Understanding, Sketching, and Information Seeking and Sharing Behavior in the New Product Design Process," doctoral dissertation, UC Berkeley, 2004/2005. Part of this work includes the development of LIA (Latent Interest Analysis) used for the three recommender systems used in SMETE.ORG.

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