

# A Digital Learning Space for Science, Mathematics, Engineering and Technology Education

Brandon Muramatsu  
NEEDS—The National Engineering Education Delivery System  
University of California at Berkeley, USA  
mura@needs.org

**Abstract:** The emergence of the World Wide Web (WWW) in the early 1990's as a viable means for national and international sharing and re-use of education materials fundamentally changed our view of the way education and learning can be delivered. Internet-mediated learning environments provide mechanisms for the learner to be anyone, anywhere, at anytime. We are seeing an enormous quantity of materials being developed to support education and learning. However locating these resources and evaluating their quality can be quite difficult; not to mention the challenges faced with learning and teaching in this new world.

We are identifying and working with a set of partners to develop a *digital learning space* for Science, Mathematics, Engineering and Technology Education (SMETE). This *digital learning space* will provide access to a variety of digital learning resources and services from a federation of partners. It will serve a community of learners and instructors across the full range of SMETE disciplines and serve users from K-12 to undergraduates to lifelong learners.

## Introduction

The emergence of the Internet and World Wide Web (WWW) in the early 1990's as a viable means for national and international sharing and re-use of education materials fundamentally changed our view of the way education and learning can be accomplished. Internet-mediated learning environments provide mechanisms for the learner to be anyone, anywhere, at anytime. We are well into this revolution, we are witness to the first steps in the democratization of learning. Faculty and students across the world are struggling with this redefinition of learning. The Internet and World Wide Web, as key tools in the learning process, are fundamental to this revolution. We are seeing an enormous quantity of materials being developed to support education and learning. However locating these resources and evaluating their quality can be quite difficult; not to mention the challenges faced with learning and teaching in this new world.

In response to these problems, two key National Science Foundation (NSF) reports, "Systemic Engineering Education Reform: An Action Agenda" (NSF, 1996a) and "Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology" (NSF, 1996b), urge the formation of a national resource to provide access to quality learning objects and to disseminate successful educational practices.

This broad vision of this national resource, a *digital learning space* for educators and learners, requires an integrated, multi-disciplinary view of Science, Mathematics, Engineering and Technology Education (SMETE). Since the early 1990's, NEEDS—The National Engineering Education Delivery System (see [www.needs.org](http://www.needs.org)) has provided this vision for the engineering education community. NEEDS enables new pedagogical models based on Internet-mediated learning environments (Agogino, 1994, Wood, 1996).

We view this national resource serving a community of learners in science, mathematics, engineering and technology education that encompasses faculty, students and life-long learners. We see community members interacting with one another to develop, locate, use and recommend to each other resources to enhance learning. As a digital learning community, community members—both novices and experts in technology enhanced learning—work together to improve science, mathematics, engineering and technology education in their classrooms, in their coursework, across disciplines and with each other. We feel it is important to recognize that this resource is much more than just a traditional academic library in digital form (Muramatsu, 1999).

This paper will provide a brief overview about the development of a *digital learning space* for science, mathematics, engineering and technology education. After a brief overview of our experiences with NEEDS—The National Engineering Education Delivery System, we will outline some of the key issues in developing a SMETE Digital Library.

## Background on NEEDS

NEEDS provides a resource where both instructors and learners can search, access, and download digital learning resources over the World Wide Web in Science, Mathematics, Engineering and Technology. NEEDS is expanding its services to include more user-centered support mechanisms, such as “Amazon.com”-like user comments and reviews. The services and features under development are designed to allow NEEDS to meet the needs of diverse user groups—some may use it to locate resources, others may use it to find like-minded educational innovators, while still others may simply want to get a glimpse of how to integrate technology and learning. NEEDS also supports a multi-tier evaluation system (Synthesis Coalition, 1995, Eibeck, 1996, Muramatsu, 1997) including a national award competition—the *Premier Award for Excellence in Engineering Education Courseware*.

NEEDS is the distributed architecture developed by Synthesis: A National Engineering Education Coalition (see [www.synthesis.org](http://www.synthesis.org)) to support the development, use and reuse of digital learning resources. We maintain strong ties to the best of state-of-the art research in databases, information retrieval, and digital libraries. These ties to research coupled with a production focus have allowed us to evolve NEEDS in sync with the rapid changes occurring with information technologies in order to meet the needs of our users. From its debut in the early 1990’s as a “text-based search engine over a centralized library catalog with pointers to digital course material” accessible via telnet (Ago-gino, 1994) to its transition to the Web in 1994 to the current system, NEEDS has undergone three major updates in response to users’ needs collected through surveys of faculty and students in engineering education. NEEDS is ultimately about providing a service to our user community; we apply the appropriate technology to meet our users’ needs. Along the way, we have developed and implemented key elements in a reliable, distributed, scalable system architecture, including: redundant Web servers; an integrated database with WWW-based searching and downloading, utilizing state-of-the-art database and information technologies; and an indirection system to support multiple, nationally-distributed archive servers for courseware download (Muramatsu, 1998, Muramatsu, 1999).

## Developing a Digital Learning Space for SMETE

The National Science Foundation (NSF) is in the process of developing a SMETE Digital Library. This program is envisioned as a federation of services and collections that function together as a *seamless* digital learning community. It will be accessible to all, from faculty to students to independent learners, and from K-12 to undergraduates to lifelong learners. It will be responsive to users needs and will focus on developing a community of users. Most importantly it will be driven by, facilitate and promote change in SMET educational innovations (NRC, 1998, NSF, 1998, NSF, 1999).

Our experience with NEEDS and our recent expansion into the other disciplines within the SMETE umbrella make us uniquely positioned to take the lead in developing the SMETE Digital Library. However as we note in the introduction, this entity will be much more than the “traditional academic library in digital form.” Through NEEDS, we have developed a platform that serves as the foundation for a *digital learning space* for SMET education. Critical to creating this system will be developing strong collaborations with partners across the target disciplines, and the development of an infrastructure and recommendation of standards to ensure quality, access, usability, reliability, stability and interoperability.

### Partnerships

We are in the process of working with the partners that we envision will form the basis for a federated SMETE Digital Library. Ultimately a wide variety of partners will be necessary, some will provide access to collections while others will provide services or the core infrastructure about which the federation is developed. A breadth and depth of partners is necessary to provide the rich user experience envisioned for the SMETE Digital Library.

We are currently working with existing collection providers, the Math Forum (see [forum.swarthmore.edu](http://forum.swarthmore.edu)) and the Eisenhower National Clearinghouse (see [www.enc.org](http://www.enc.org)), to form a prototype SMETE Digital Library. The prototype is built upon NEEDS, and through it we will test federated searches, exchange of metadata and shared services as a prelude to developing a full-scale SMETE Digital Library. In addition we will continue our user studies across the full range of the partners’ user communities (K-12 and higher education, as well as the disciplines in the sciences, mathematics and engineering).

We envision collection providers such as NEEDS, the Math Forum, the Eisenhower National Clearinghouse and the newly formed the Geosciences Digital Library will form the core about which the SMETE Digital Library will develop. These organizations are working within their own communities to determine the services and features necessary to provide value to their users. The challenge will be bringing these partners together to determine core services and features common to the SMETE Digital Library. In addition we must plan for identifying and adding additional partners to support the broad reach of the sciences, mathematics, engineering and technology.

### Interoperability and Metadata Standards

Standards will play a key role in the development of a federated SMETE Digital Library. Standards will provide mechanisms for sharing metadata about resources, and will provide the means to accomplish interoperability be-

tween federated systems. The Institute for Electrical and Electronics Engineers (IEEE) is in the process of working with the community-at-large to develop standards for learning technologies in Working Group P.1484 (see [ltsc.ieee.org](http://ltsc.ieee.org)). Also, the digital library research community and general library communities have developed standards for interoperability that we can adopt or adapt to suit the needs of a *digital learning space* for SMETE.

The SMETE Digital Library is envisioned as a federation of collections that share the ability to discover resources across collections as well as share services between resource providers. To accomplish this sort of interoperability we can look to the work being developed by digital library researchers and apply it to the SMETE domain. The Dienst and Waters protocols are two examples that are in use today in the Networked Computer Science Technical Report Library (see [www.ncstrl.org](http://www.ncstrl.org)). The Networked Digital Library of Theses and Dissertations (see [www.ndltd.org](http://www.ndltd.org)) in Computer Science is also experimenting with protocols to perform federated searches over its distributed collection (Powell, 1998). Researchers at Stanford University are developing a Simple Digital Library Interoperability Protocol (SDLIP) in use locally within their digital library and in conjunction with the digital library research project at the University of California at Berkeley (Paepcke, 1996, Paepcke, 1998, Stanford Digital Library Project, 1999). These three examples combined with standards such as Z39.50 and the use of extensible markup language to encapsulate searches (Maly, 1999) are some of the areas we will be exploring as we develop specifications for interoperability in the SMETE Digital Library federation.

The development of metadata standards to describe a digital learning resource is another key concern. Current standards efforts (IEEE P1484.12), and the work of various international groups such as IMS (see [www.imsproject.org](http://www.imsproject.org)) and ARIADNE (see [ariadne.unil.ch](http://ariadne.unil.ch)), have focused on describing the content of the learning resource. In August 1999, IMS released its version 1.0 metadata specification based upon the learning object metadata work in the IEEE standards process (IMS, 1999). In addition, groups such as the Math Metadata Working Group, and some of our early efforts with NEEDS in engineering, are developing discipline-based subject hierarchies. These subject hierarchies will allow the user to both browse for learning resources he/she may be looking for as well as assist searchers in finding related materials.

NEEDS and SMETE Digital Library prototype (as it is built upon the NEEDS platform) are committed to implementing and participating in the development of standards and specifications for metadata and content description. From its inception NEEDS has placed a high degree of importance on standards, for example the USMARC standard for bibliographic cataloging (Synthesis Coalition, 1993). NEEDS recently adopted the IMS Metadata Specification version 1.0 and the related proposed IEEE Learning Object Metadata standard version 3.6. We feel it is important to be a key player in the development of these items, we bring almost ten years of experience in running a production system that takes advantage of these standards and specifications. We also feel it is important to take the lead in the development of specifications to better encapsulate the context in which a learning resource is used. Finding the materials is only a small part of the challenge facing educators and learners today, knowing what to do with the materials poses the tougher challenges.

### **Community of Learners and Pedagogical Applications**

The current metadata and subject hierarchy work is focused at developing methodologies to better describe the content of a resource. However, moving beyond the learning object itself leads to the question, "How do I use these learning resources once I've found them?" This is an area in which much work is clearly needed. The first steps are already being taken in the NEEDS platform to develop support mechanisms to allow a community of users to discuss and recommend pedagogical applications/uses of a learning resource.

The long term vision of our community building efforts is to facilitate users searching for both content as well as educational concepts (e.g., geometry or problem based learning). This evolution to support communities of learners emphasizes interactivity, user-to-user communication and community building. Two steps we are taking right now are allowing users to post reviews (i.e., "Amazon.com"-like reviews) and participate in focused discussion groups (e.g., freshman design). It may be possible, however, to go further; we envision "pedagogical metadata" that better encapsulates or packages the pedagogical applications of a learning resource.

At a recent workshop, one of my co-presenters mentioned that metadata is "difficult and boring." Yet the use of metadata is critical to describe resources in a manner that allows a user to find them. Current collection providers have provided the first part of the needed solution—tagging the content. In some cases they have taken small steps in describing the much needed part, that of pedagogical application of the resource. For example, the Math Forum and NEEDS provide authors the ability to describe the type of learning resource at a basic level. The current efforts in metadata provide a macro-level view of the pedagogical application of a learning resource. What's needed is a micro-level, or more granular, view of how to use a particular resource. We envision collection providers continuing to provide the basic tagging of the content of a resource. However, we also see them working to develop an author/instructor completed "short form" that describes the pedagogical application of a resource. From this "short form" we envision being able to extract a much richer set of descriptions about possible applications of the learning object. This "short form" combined with culling discussions about resources we feel will ultimately allow us to provide a better description of the context in which to use a learning objects.

## Summary

The frenetic pace of change in information technologies has exacerbated the age old problem of finding information. With everyone a “publisher” in this new information age, the volume of materials is drastically increasing. Even if we “just” limit ourselves to engineering education, the volume is enormous. NEEDS is developing a new vision, a *digital learning space*, that extends beyond a single discipline. It encompasses a federation of collection and service providers to support the learning and teaching needs of a broad community of learners in the sciences, mathematics, engineering and technology education.

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## **About the Author**

Brandon Muramatsu is the Project Director for NEEDS and the SMETE Digital Library prototype projects. He is a lecturer in multimedia at UC Berkeley, directs the Berkeley Instructional Technology Studio and is past Chair of the San Francisco Section of the American Society of Mechanical Engineers. Mr. Muramatsu received his B.S. degree in 1993 and M.S. degree in 1995 in mechanical engineering from the University of California at Berkeley.