Serving the Needs of Pre-College Science and Mathematics Education: Impact of a Digital National Library on Teacher Education and Practice. Proceedings from a National Research Council Workshop

Executive Committee
Mathematical Sciences Education Board
Center for Science, Mathematics, and Engineering Education

National Research Council
Washington, DC 1999

NRC NAS NAE IOM

Serving the Needs of Pre-College Science and Mathematics Education: Impact of a Digital National Library on Teacher Education and Practice.

Proceedings from a National Research Council Workshop

Executive Committee
Mathematical Sciences Education Board
Center for Science, Mathematics, and Engineering Education

National Research Council
Washington, DC1999

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

The National Research Council (NRC) is the operating arm of the National Academies, which includes the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The National Research Council was organized in 1916 by the National Academy of Sciences to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and providing impartial advice to the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Bruce Alberts, President of the National Academy of Sciences, and Dr. William A. Wulf, President of the National Academy of Engineering, also serve as chairman and vice chairman, respectively, of the National Research Council.

The Center for Science, Mathematics, and Engineering Education (CSMEE) was established in 1995 to provide coordination of all the National Research Council's education activities and reform efforts for students at all levels, specifically those in kindergarten through twelfth grade, undergraduate institutions, school-to-work programs, and continuing education. The Center reports directly to the Governing Board of the National Research Council.

This study by CSMEE's Mathematical Sciences Education Board was conducted under a grant from the National Science Foundation (**DUE-9727710**) to the National Academy of Sciences/National Research Council. Any opinions, findings, or recommendations expressed in this report are those of the members of the Committee and the authors and do not necessarily reflect the views of the National Science Foundation.

Printed in the United States of America.

MEMBERS OF THE EXECUTIVE COMMITTEE OF THE MATHEMATICAL SCIENCES EDUCATION BOARD

HYMAN BASS (CHAIR), Columbia University
JERE CONFREY (VICE CHAIR), University of Texas at Austin
DEBORAH L. BALL, University of Michigan
GLENDA T. LAPPAN, Michigan State University
MARK SAUL, Bronxville Public Schools
EDWARD A. SILVER, University of Pittsburgh

STAFF

JAY B. LABOV, Director, Division on Postsecondary Policy and Practice, Center for Science, Mathematics, and Engineering Education
TERRY K. HOLMER, Senior Project Assistant Center for Science, Mathematics, and Engineering Education

REVIEWERS

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's (NRC's) Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making the published report as sound as possible and to ensure that the report meets institutional standards for objectivity and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in the review of this report:
MARY COLVARD, Cobleskill-Richmondville High School
ARTHUR EISENKRAFT, Bedford Public Schools
ENRIQUE GALINDO, Indiana University
TOBY HORN, Thomas Jefferson High School for Science and Mathematics
MIRIAM MASULLO, IBM Watson Research Laboratory
KURT MOSES, Academy for Educational Development
JAMES SERUM, Hewlett-Packard, Inc.

While the individuals listed above have provided many constructive comments and suggestions, responsibility for the final content of this report rests solely with the workshop planning committee and the National Research Council.

TABLE OF CONTENTS

BACKGROUND

In 1997, the National Science Foundation (NSF) asked the National Research Council's Center for Science, Mathematics, and Engineering Education (the Center) to study the feasibility and logistics of establishing a digital national library (DNL) for undergraduate science, mathematics, engineering, and technology education. The NSF envisioned that this resource would most likely be available to users via the Internet and would provide a comprehensive resource where users from the many communities involved with the teaching and learning of science, mathematics, engineering, and technology (SME&T) could reliably locate high quality information, materials, and software tools to enhance education. In response, the Center convened a workshop on August 7-8, 1997 with more than 50 people from academe, publishing, scientific societies, information technology companies, and others in attendance.

By the end of that workshop most participants indicated that the idea of a digital national library is sufficiently promising that federal agencies should continue to pursue it. However, workshop participants also acknowledged that many issues needed to be resolved before such an entity could come into existence, including questions of audience, the source of materials in the library, the organization of those materials, methods of funding the effort, the protection of intellectual property, the technology it would use, ways of evaluating materials submitted or included in the library, and the organization or people who would be charged with maintaining and updating the resource..

A central issue that permeated the workshop was who the potential users for a digital national library might be. Workshop participants argued that most other questions about the feasibility and logistics for establishing a DNL hinged on deciding on the likely community of users and then establishing their needs. For example, would users be limited to undergraduate faculty and students, or would the potential user population be much broader, encompassing pre-college students and teachers as well as adult learners of all ages? What materials should be included in such a resource, given the range of potential users? What impact would a digital national library be expected to have on different users?

To address these questions, the report from the steering committee for the workshop (National Research Council, 1998) recommended that the NSF[1]

- Make a concerted effort to bring together in a series of focus groups representatives from all the communities that might be a national library's likely users and service providers.
- Articulate its priorities for content, technological considerations, and economic and legal models before committing to the establishment of an NL.

[1] The executive summary from the report that resulted from that workshop (National Research Council, 1998) can be found in Appendix A, page 19).

- Examine whether the proposed NL should commission the creation and storage of materials vs. developing a sophisticated system of pointers to materials that reside and are maintained elsewhere.
- View such a resource as one that would contribute to improving and inspiring learning of undergraduate SME&T in addition to providing tools and resources to promote more effective teaching of these subjects.
- Appoint a Board of Overseers that is charged to work with a broad spectrum of intended users and other stakeholders before deciding what kinds of materials and in what fields of SME&T should be placed into the proposed NL both initially and over the longer term.
- Emphasize involvement by professional SME&T societies in developing content that could be appropriate for an NL.
- Include in an NL information about and access to projects in undergraduate SME&T education that the NSF and other agencies have supported financially.
- Develop and issue one or more Requests For Proposals (RFPs) to establish an NL for undergraduate SME&T education. The Steering Committee recommended that RFPs for preproposals not be formulated until the NSF sponsors the focus groups described above. Feedback and evaluation of information from these groups of users and providers could then serve as the basis for constructing RFPs that would help eventual awardees to address specifically the established needs and requirements of potential NL users.

Given the Steering Committee's strong emphasis on communicating with potential groups of users prior to committing to any particular design structure for a NL, the NSF asked CSMEE to convene a second workshop with a diverse group of people from the high school mathematics, science, and technology communities. The Center vested responsibility for oversight of this project with the Mathematical Sciences Education Board (MSEB). MSEB is one of four standing boards and committees at the Center[2] and has played a central role in examining ways to improve mathematics education, including the preparation and professional development of K-12 teachers. MSEB appointed Lee Jenkins, a member of MSEB, as the coordinator and facilitator for the project. The workshop was held on September 24-25, 1998.

Most of the focus of this workshop was on science and mathematics for grades 9-12, although for some issues workshop participants[3] also broadened the discussion to include grades K-12. Thus, in this report, text that describes activities or issues that focus solely on teachers or

[2] The Center's other standing boards and committees are the Board on Engineering Education, Committee on Undergraduate Science Education, and the Committee on Science Education for Grades K-12.

[3] A list of workshop participants is provided in Appendix B. Biographical sketches of workshop participants are listed in Appendix C.

students in high school refers to "grades 9-12." The report uses the term "pre-college" to describe issues or information that could extend to grades K-12.

Representatives from these communities were asked to offer their perspectives on several central questions:

- How might a digital national library for undergraduate science, mathematics, engineering, and technology education best serve the needs of high school teachers of mathematics, science, and technology, teacher educators in these disciplines, and professional organizations for teachers?
- What kinds of materials could the pre-college community contribute to the content of a digital national library?
- How can this resource best serve the needs of future pre-college teachers? In other words, how can it be used in pre-service education and for practicing teachers, for continuing development, for teachers of science, mathematics, and technology?
- How can this resource best serve the needs of professional societies and organizations for teachers to do the kinds of jobs that they have to do?
- What materials and resources can this community contribute to a DNL that would be useful to both the pre-college and undergraduate communities was well as for lifelong learners?

This report summarizes the discussion at the workshop, highlighting important issues raised by workshop participants about the use of a digital national library by the pre-college community.

ORGANIZATION OF THE SECOND WORKSHOP

The agenda for the workshop is presented in Appendix D. The first day of the workshop was to be devoted to articulating whether and how members of the high school science and mathematics communities might take advantage of the content of the proposed DNL. Discussion focused on the kinds of information and resources that could best meet the needs of these communities of users, how a DNL could most enhance teaching and learning for pre-service teachers, and how the DNL could engage the broadest spectrum of users from the high school community to utilize this resource. Other issues discussed on Day 1 included:

1) the educational and technological barriers that teachers face that would limit their access to and utilization of the proposed DNL, and
2) what the designers of the technological aspects of this resource should consider to address these barriers to usage.

Prior to coming to the workshop, each participant was asked to consider the following questions:

As a potential user (teacher or learner) of a digital national library for science, mathematics, and technology education, what would have to be available in this facility, both in terms of content and services, for you to

1) *initially log into this resource, and*
2) *use it consistently for your teaching or learning?*

For the second day of the workshop, participants were asked to discuss the kinds of electronic products and materials that are currently available in mathematics, science, and technology for high school teachers and students that could enhance the holdings and utility of the DNL for both the pre-college and undergraduate science, mathematics, engineering, and technology communities.

However, discussions of these topics did not proceed linearly as had been originally planned. Consideration of what would be required for teachers to initially log into this resource and to use it consistently became an explicit or implicit part of virtually every topic discussed throughout the two days of the workshop. These issues that had been planned for discussion only during Day 1 attracted so much attention that they continued through much of Day 2.

Similarly, discussion of the kinds of resources that the pre-college community might contribute to a digital national library for undergraduate SME&T education were covered as part of the discussions on Day 1 (see ***Examples of Current Systems*** beginning on page 7). Because consideration of Day 1's issues extended into much of Day 2, the question about resources that the pre-college community could offer to the NL was considered only in a cursory fashion on the second day.

WHAT MIGHT THE DIGITAL NATIONAL LIBRARY BE?

INTRODUCTORY REMARKS

The workshop began with introductory welcoming remarks by the workshop facilitator, the executive officers of CSMEE, and Dr. Frank Wattenberg, NSF program officer in charge of the Division of Undergraduate Education's digital library initiative. Following those introductions, Jay Labov of the National Research Council next summarized the conclusions of the August 1997 workshop and the ensuing report (National Research Council, 1998) on developing a digital national library for undergraduate science, mathematics, engineering, and technology education (Executive Summary from that original report is reproduced in Appendix A, page 19). Defined most broadly, the library would be a set of electronic resources and associated technical capabilities for creating, searching, and using information that would be available on the Intemet and possibly via other electronic formats. But a digital national library would be different from a traditional library in being not only used but created by groups of people. Such a library would be “constructed, collected, and organized by a community of users,” said Labov. “In other words, it's the community that can define what should be in the library and the services that it can provide.”

Participants at the first workshop initially thought that the community of users would primarily be college faculty. But as the discussion progressed they soon realized that the actual community of users and contributors could be much larger. “It [the user community] could be college students, graduate students, high school students,” said Labov. “It could be adults who are lifetime learners. It could be people who are coming back into community colleges and higher education after having worked. And it could be many other groups, such as professional organizations that are trying to serve their memberships by providing various kinds of information for them.”

The content of a digital library could be equally diverse. It could range from raw data generated by experimental instrumentation in scientific laboratories or from educational research to peer reviewed articles. Educational materials could include course syllabi, reading lists, lab exercises, or entire textbooks. Furthermore, the content would not be static. Depending on the organization and procedures of a digital library, individual users might modify and improve upon the library's content. **In this sense, remarked Miriam Masullo of IBM, it may not be possible to define a digital library without the idea of a community of users for a working definition of a “user community” as the term is employed in this report, see footnote 2 in Appendix A, page 21). Rather, the library would be defined to a large extent by and for its own identified user community.**

Labov noted that discussion at the previous workshop revolved around a number of difficult questions associated with a national digital library. Among those questions are:

- How would the content in such a library be organized and accessed?
- Should the material in the library be archived in a single location, or should the library merely point to where the material is stored?
- How can the quality of the material in a library be assessed and made public?
- Who would own the intellectual property contained in a digital library?
- How would it be funded, and who would oversee its operations?
- How compatible should the material in the library be with existing hardware and software?
- How could the material be kept up to date, and how long should it be kept in the library?
- How could equitable access to the library be guaranteed to everyone who could benefit from it?
- How should potential users be trained to take advantage of the library?
- How could privacy for users be maintained and protected?

Participants at the present workshop acknowledged the difficulties surrounding many of these questions. But they also emphasized the great value that a digital national library would have for the pre-college community. “Electronically-based media offer some dimensions that are very different from paper-based media,” said Frank Wattenberg. “They offer the possibility of creating a very rich learning environment, an environment that includes interactive materials, programs, and tools that students can use as well as text-based material. So it's a very active environment. It's also a very connected environment. Students can go off and get primary material. They can get census data. They can get real-time data from Mars.”

Other workshop participants pointed to a number of other advantages of electronically based media. They can be interactive, which distinguishes them from more passive media like television. Material available through these media can be extremely current—much more so than information available through documents published in more traditional formats. And students can work together across institutions, countries, and cultures.

The learning experiences available through electronic media can be particularly empowering for students. “One of my seniors became interested in a specific topic in plant science, which we discovered was in a report from in Scandinavia,” recounted Toby Horn of the Thomas Jefferson High School in Virginia. “So we went to the National Agricultural Library's website and then requested the report. That child is now majoring in natural resources. This was one of those crystallizing events that he could see: My idea connects with someone else's.”

A digital library also would complement other kinds of educational materials. Kimberly Roempler of the Eisenhower National Clearinghouse cited an example of a physics textbook that has a website with links and online projects organized chapter by chapter. Other websites offer supplemental materials that can allow students to catch up with a lesson or go beyond the material presented in a class. A digital national library could make it possible to extend the size and diversity of the community involved in education. For example, it could provide a way of getting parents and families more involved with the schools. “Parents could go into a section dealing with homework, find the concept, and help their child,” said Katylee Hoover of the National Science Foundation. It also could support the provision of educational resources for a multicultural society, reflecting different social and educational practices within society. In general, electronic resources could foster the growth of virtual communities organized around common interests.

One of the most important of these communities consists of teachers and teacher educators. Using these tools, teacher educators could remain in touch with their students for many years after graduation. Moreover, students who shared courses and other preservice experiences could maintain contact and engage in discussions with each other more easily than would be possible via other electronic methods such as e-mail. Discussion areas in a DNL for teachers and teacher educators also would facilitate the sharing of information and ideas across universities and school districts on issues of common concern. According to Wattenberg, “We can create virtual communities in which our pre-service teachers are talking with our in-service teachers, so the pre-service teachers are going to be better prepared for what they are actually going to face in the classroom; and the in-service teachers can keep in touch with the cutting edge in science and mathematics education."

The technical capabilities of a digital national library further increase its potential in education. For example, teachers interested in particular curricular or pedagogical issues could be notified automatically of new offerings in their areas of interest or study. Students could conduct individualized research through the library with a community of other students anywhere in the world.[4] If structured properly, search engines could enable users to locate the materials they want even in the midst of tremendous quantities of resources. Assuming that access to the library is equitable, students everywhere would be able to get cutting-edge material. According to Wattenberg, "The NSF has supported an enormous number of very high quality projects that have produced excellent material and simply haven't had the wide impact we would have liked. It's hard for things today to be widely disseminated. The principal means has been publishing. [A digital library] offers another possible means."

As was the case at the original workshop, participants at this workshop discussed the benefits of a digital national library for a number of potential communities of users. These communities include teachers, students, parents, and professional organizations. Although these communities have many interests and needs for resources in common, they also have differing requirements for and interests in the kinds of materials that might be placed in a NL. Current workshop participants did not consider in depth the ramifications of these possible differences in the type of materials or their level of sophistication that different user communities would desire in a NL. However, the fact that discussions at this workshop also included all of these user communities reinforces the issue of defining the breadth of the community of users before beginning to construct this resource.

EXAMPLES OF CURRENT SYSTEMS

Participants at the workshop spent considerable time examining and discussing several websites that could act as models or prototypes of a pre-college extension of the digital national library.

[4] The idea of users contributing their own work and research data to a digital library was specifically addressed in the original workshop. Participants at that workshop proposed that a section of the digital national library be set aside for such a purpose. This section might undergo less rigorous scrutiny by the governing body for content and be available as a public forum for the sharing of data, new reports, and educational software under development. For additional information, refer to points 3 and 6 on page 25 in Appendix A).

Eisenhower National Clearinghouse

One of these websites is maintained by the Eisenhower National Clearinghouse (ENC) for Mathematics and Science Education.[5] The ENC is a centralized site that gathers educational materials and makes them available from its own computers. Content specialists find and acquire the rights to materials, write abstracts for the resources on the site, enter data, and maintain the site catalog—a resource-intensive process that ensures quality while slowing somewhat the provision of resources. A search engine allows users to find the materials in which they are interested. The site is currently getting more than 2 million hits every month, and the clearinghouse expects that number to grow substantially.

ENC also provides links to related and recommended sites. A frequently updated “Digital Dozen” points visitors “to what we think are the best sites and the best resources available,” said Roempler, who directs the Instructional Resources Division of the Clearinghouse. Links to regional consortia and collaborators enable users to find local contacts. The budget for the website is about $4.6 million per year, with funding provided by the Department of Education. The Clearinghouse has limited means for raising money, according to Roempler, and is dependent on continued federal funding. Evaluations of ENC products (including their website) have been conducted through surveys of users, but the actual impact of the resources it provides is difficult to measure.

Educational Resources Information Center (ERIC)

A somewhat different model is provided by the *Gateway to Educational Materials* (GEM) site, maintained by the U.S. Department of Education's Educational Resources Information Center (ERIC).[6] GEM is a guide to educational material on the Internet. According to the National Library of Education's Keith Stubbs, “we are trying to develop a way to distribute the work so that the authors and creators of material can do some classification and cataloging of their work, and we can then gather that information into this gateway.” Like the ENC collection, GEM offers search engines so that users can find specific materials. But unlike ENC, GEM is a distributed model that points to resources that reside on many different computers and computer networks rather than collecting and cataloging those resources.

At this point, GEM has about 3,000 resources in its database. “That doesn't cover the whole Internet yet,” said Stubbs. “But we have a mechanism that could grow if it's handled well.” Participation in GEM is voluntary, Stubbs said. There are no financial incentives for being listed in the database. “The incentive is that more people will find you.” GEM is one of about 30 websites maintained by ERIC.

[5] Available at: <http://www.enc.org/index.htm>

[6] Available at: <http//geminfo.org>

Another ERIC website is *Ask Eric,*[7] which gets about 1,000 questions from teachers each week. There are at least 70 other “ask an expert” services on the Internet, according to Stubbs.[8]“We are trying to develop a community of these people to share best practices, tools, and knowledge so that people can do referrals,” he said.

The Federal Resources for Educational Excellence (FREE) site.[9] FREE is an interagency website of the federal government that is maintained by the U.S. Department of Education. It provides links to hundreds of Internet-based educational resources supported by agencies across the federal government. Resources are listed by subject or can be searched, and the site invites curriculum developers to participate with federal agencies in developing and making available new materials. Content at this website is organized using GEM's subject classification system.

Genentech's Access Excellence

Workshop participants also visited several privately maintained websites. One is *Access Excellence,*[10] a website supported by Genentech, Inc., that is designed primarily for and by high school biology teachers. About three hundred teachers who competed successfully to become fellows in the program received a laptop, modem, and printer. These teachers provided descriptions of their teaching philosophy, their methods of working with other teachers, and sample lessons. These inputs provided the basis for the site, which is now used by teachers from across the United States. Additional features include a collection of innovative teaching ideas and activities, online forums and internet data collection collaborations where teachers can discuss new ideas and best practices, and news articles and other information useful to biology teachers.

National Research Council's Project RISE

Project RISE,[11] a website intended to increase the involvement of scientists and engineers in public education, took a different approach to the presentation of exemplary materials. It offered about a dozen examples of exemplary projects that showed the different kinds of roles that scientists and engineers could play in improving pre-college science and technology education. The website also posted articles and other published documents that described how scientists and engineers had gotten involved in pre-college education.

The site was developed with extensive participation from the intended users. A working conference of about 25 leaders of successful partnerships guided the design of the site. The same group field-tested the site to refine it.

[7] Available at: <http://eric.syr.edu>

[8] For example, see the Virtual Reference Desk at <http://www.vrd.org>

[9] Available at: <http://www.ed.gov/free>

[10] Available at: <http://www.gene.com/ae>

[11] Available at: <http://www.nas.edu/rise>

Though the site still exists, it is no longer being funded and now is minimally maintained. “We have to remember not to be overly optimistic about our resources,” said Jan Tuomi, who organized the site for the National Research Council and described her experiences at the workshop. “The resources needed to maintain a site are significant, especially the more interactivity or resources that you promise people…You have to make sure that you have a layered approach so that you know you still maintain a core layer even if resources get tight.”[12]

One interesting point made about some of the websites examined is that they do not necessarily have to be provided over the web. Self-contained sites like *Access Excellence* or *ENC* can be provided through other means, such as from a CD-ROM or other technology. That removes the need for a user to move from website to website, which always risks a busy signal or nonfunctioning links. More direct access to information also can better match the needs of teachers. Teachers often may download and save information or collect resources from a variety of sources for both immediate or later use in their classrooms. They don't necessarily need realtime access to the information being used. Rather, said Kurt Moses of the Academy for Educational Development, teachers need to control the content, sequence, intensity, level, and behavior of the materials they are using. “Just-in-time information may be fine for banking,” said Moses. “But is it fine for teaching?”[13]

The other advantage of self-contained sites, said Masullo, is that they can help equalize access. A device called a proxy server can function as a predigested web site without the need to pay for real-time connections to the Internet[14]. Digital Broadcast Satellite (DBS) technologies can be used to refresh gateway servers at the rate of some 600 megabytes of content (approximately the content of a CD-ROM) in ten minutes. From those gateway servers, information can be disseminated via standard cable (in addition to the Internet), for broader access. DBS, which is, by definition, wireless also can reach users directly in isolated or remote areas where cable and Internet access are scarce, providing them with rich multimedia and interactive experiences. Such delivery systems could be critical for increasing equity of access to information from a NL. Using satellite or ground-based technology, said Masullo, “overnight I

[12] Tuomi indicated that establishing this website cost more than $250,000 over 24 months. In addition to the costs associated with the building of the site, expenses for this project also included other activities of the project such as workshops to promote the website at meetings of scientific professional societies.

[13] In 1999, the National Science Teachers Association (NSTA) opened sciLINKS, a website that provides teachers, students, and parents with digital resources that supplement a number of major science textbooks being used in K-12 classrooms today. SciLINKS offers websites to extend and expand students' understanding of science, breaking science news to add context to classroom learning, science activities, and experts to answer questions. According to the announcement of this new website, “NSTA places sciLINKS icons and codes in textbook margins at key subject areas. By accessing the sciLINKS web site and entering the code, students and teachers are guided to professionally selected web sites that support the particular science subject introduced in the text.”

[14] A proxy server stores documents or data that are frequently accessed by a defined group of users. The proxy server automatically requests information from the original source only when that source has been updated or has expired. This process reduces network traffic and gives the proxy server's users access to fresh content without waiting. Documents or entire sites can be preloaded into the proxy server. Whole sites can be downloaded during low-traffic periods, for example, so they're available to users when needed. (Modified from a description provided by Netscape's Netcenter: <http://home.netscape.com/proxy/v3.5/index.html>

can refresh the information in every school in the United States. This country has 48 million students and 3 million teachers. Those are the numbers I want to reach."

Masullo also pointed out that because technological advances are occurring increasingly rapidly, it is important to look beyond current models for producing and delivering content and other resources. Although current thinking for delivery of goods and services from a NL is primarily via the World Wide Web, some new dissemination vehicle may evolve and eclipse current uses of the Internet. Masullo emphasized that people need to dream about how information technology might transform teaching and learning and allow technology to develop in parallel to those visions.

WHAT THE PRE-COLLEGE COMMUNITY NEEDS

Despite the valuable resources available through existing websites, workshop participants expressed that the pre-college community needs additional capabilities from a digital national library. First, this community needs to know what information, resources, and tools are available. Even some of the technologically savvy educators at the workshop did not know about some of the websites examined during the workshop. According to the NRC's Jan Tuomi, the conventional wisdom in industry is that advertising a website takes several times as much money as is needed to build and maintain the site. A given website would need to achieve a critical mass of users and publicity before educators could be assumed to know about it. One possible way of publicizing resources, according to Jenkins, would be through the use of a new URL instead of .org or .com—perhaps .learn or .k12. "Or .fun," suggested Moses.

The design of an electronic resource that meets the needs of the pre-college community also needs to reflect the constraints on teachers' lives and professional practice. "Teachers don't have the time [to explore all of the available resources]," said Donna Davis of the District of Columbia's Public School System. "If they are in a class with kids all day, they don't have the energy to spend three or four hours at night doing web searches. The web is overwhelming because there's so much, and it's not [currently] in any form that is usable. [We need] order out of chaos."[15] According to mathematics professor Vernon Kays, "We need to come into a site and key in a topic, age, any number of issues, and get the five or six things that are appropriate to that."

The NSF's Katylee Hoover added, "If teachers are going to use it—pre-service teachers, in-service teachers, primary school teachers—it is going to have to be simple and quick. When I teach a lesson, I want to know the [students'] prior knowledge first. Who knows about this? What do they know? Then, if a teacher already knows about that concept, she should be able to go to the level that she needs quickly."

[15] For additional consideration of this issue, see discussion under "Quality and Comprehensiveness, " beginning on page 12.

Teachers also need incentives to place materials into a national digital library. Perhaps teachers who receive federal grants to develop curricular materials and other resources could be required to do so. More broadly, ways have to be found to involve significant parts of the pre-college science and mathematics communities. “If we want a national resource, we'd better get every teacher and administrator involved,” said Masullo. “If you don't give them ownership, they won't share that kind of enthusiasm.”

Another element of an effective digital national library is what workshop participants referred to as ‘stability.' “Say I'm a teacher,” said Wattenberg, “and I spend a lot of time developing some classroom material that uses all these resources. Then, when I come back the next year, all the links are broken and the programs no longer work because I upgraded to Windows 2002. That's a lot of wasted effort. So I need stability.”

Stability is related to another issue—that of overseers of a digital library deciding how long to maintain a link or a resource in an electronic database. Should resources automatically be replaced after a certain number of years? And who would make that decision?

Sites also change their rules for access. For example, websites that were once free may begin charging for access as they become more popular. Teachers who depended on those websites for key information may no longer be able to obtain the resources they need.

The organization of knowledge is also an issue. Many teachers want a national digital library to allow learners to achieve multidisciplinary perspectives on problems. Workshop participants indicated that the developers of a digital national library for science, mathematics, engineering, and technology need to concentrate on these disciplines. But the organization of knowledge also should reflect the structure used in other disciplines and at other grade levels so that resources can be combined.

SPECIFIC ISSUES

Beyond the general needs of the pre-college community, several issues attracted particular attention from workshop participants.

Quality and Comprehensiveness

Any collection of materials must draw a balance between the competing demands of comprehensiveness and selectivity. Furthermore, the developers and users of any such collection often have different preferences. Some want to include any document or other resource that might be useful. Others want to have available only the best things selected by someone else. The same considerations would apply in a digital national library. Some teachers want as many resources as possible and prefer to make their own decisions about which ones to use. Others want decisions about quality and usability (e.g., for the grade level they teach) to be made before they access a resource. **“The feedback that I have received from teachers is that they are tired of mediocre resources and want materials that have worked for others, and therefore**

will work for them in the classroom," said Julie Ghent-Paolucci of Montgomery County Public Schools.

A digital library is particularly susceptible to the dilution of quality resources. "The difference between a digital library and a 'traditional' library is that in the traditional library all the junk that people publish doesn't make it to the library," said James Stith of the American Institute of Physics. "In the electronic world, all I need is to type it in and hit send, and it's out there and people can find it…Is the function of the digital library to separate all the stuff that is published from all the stuff that gets in the library?"

A possible compromise is to offer a comprehensive range of materials but to include reviews and recommendations with those resources. For example, one role of professional societies and organizations that represent teachers generally (e.g., National Science Teachers Association, National Council of Teachers of Mathematics) or in specific disciplines (e.g., Association of Biology Teachers, American Chemical Society, American Association of Physics Teachers), might be to provide quality checks, just as many do today with printed materials (for an example of how scientific societies might become involved with such quality checks, see the reference to NSTA's new sciLINKS website in footnote 13 on page 10). Or, materials could be categorized and described by their developers, although the motives of the reviewer would have to be considered. "Are they going to describe things in terms that are descriptive or in terms that are advertising?" asked Stubbs.

Materials also could be categorized according to the amount of review they have received. For example, materials that have been peer reviewed could be in one part of the library, with non-peer-reviewed material in another section. Perhaps another section could include material that has been reviewed by users who have improved upon that material. The obvious drawback of such a scheme is that reviewing inevitably takes time, whereas materials placed directly on the Internet can appear immediately. Decisions about what is placed into the DL ultimately would be the responsibility of the board of overseers for this resource (also see the Executive Summary from report of the first digital library conference, Appendix A, page 25).

Finally, it is unrealistic to expect that everything will be available somewhere on the web. "You're not going to find everything that you need out there [on the Internet]," said Roempler. Some material will need to be added by the community of users in response to recognized needs.

This need for users to add to the content of a NL also raises the issue of how users can most easily gain access to the kinds of tools needed to produce lessons, software, and other products that would be amenable to the digital format of this kind of resource. Would such tools be available through the NL itself? Would contributors be expected to develop products using only certain software authoring tools? Would technical assistance be available to people who wish to develop such tools or products? Who would be responsible for reviewing such products before the NL accepts them for dissemination?

In addition, the hypertext/hyperlink architecture of the World Wide Web is very different in structure from the kinds of curricular materials that teachers have traditionally used for teaching. Can new digital curricula be constructed that better match the needs and expectations of teachers and students? Or, will the digital revolution so permeate education that current notions of curriculum and other teaching and learning tools will yield to new paradigms?

Articulation and Standards

A national digital library could help address one important problem in education today—the lack of articulation between different parts of the educational system. The Advanced Placement classes offered in high schools are a case in point, according to Lee Jenkins. Classes for non-science majors in college are another example where articulation between high school and higher education needs improvement. The same kinds of experiences that will build interest in science and mathematics could be used with appropriate modification in both college and high school settings. Also, if students coming into college had a better idea of what was expected of them in science and mathematics, and if college faculty were more familiar about the level of science and mathematics taught in high schools, students who enter college would be more likely to succeed in their study of these disciplines.

A digital national library could provide a mechanism for college faculty and teachers and administrators, especially in grades 9-12, to discuss such issues, with people from organizations like the College Board and the Educational Testing Service joining in. “We could think of a large number of topics where people who really need to talk with each other are not doing so,” said Labov. “We could make it [the digital national library] a forum for national and worldwide discussions of many of the things that we are not talking about in education.”

Different communities could learn much from each other in this way. For example, the pre-college community is more accustomed to collaborative enterprises than is the higher education community. Could colleges and universities learn to work more collaboratively by having greater interactions with pre-college teachers? “I have spent my whole life in universities,” said Wattenberg. “There is no equivalent to teacher leaders in universities, at least none that I know. There may be some things that we can learn here for undergraduate education from [such models in grades] K through 12.”

Another feature of a digital national library is that it could support the drive for educational standards. **Virginia, for example, is providing links from its standards document on the web to sites that support those standards. Other states and professional organizations that are involved with standards have already made their documents available on the Internet**[16] **or are likely to do so in the near future. This linkage between national and state standards and curriculum frameworks and educational resources could provide one approach to accountability.** “As an administrator, you hold your teachers responsible for the syllabus and the curriculum and certain landmarks,” said Masullo. “By

[16] E.g., National Science Education Standards (National Research Council, 1995):060;http://www.nap.edu/readingroom/enter2.cgi?ED.html>;*Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993): <http://project2061.aaas.org/tools/>; Mathematics Standards and the forthcoming Standards 2000 (National Council of Teachers of Mathematics (1988 and in preparation): <http://www.nctm.org>

linking standards to particular educational resources, administrators and the public could have more confidence that those standards were being achieved."

Teacher Education

Modern information technology offers multiple avenues to teacher education. For example, teacher facilitators could be available electronically to interact with individual teachers or groups of teachers. The Eisenhower National Clearinghouse offers such a service focused specifically on teacher leaders within schools.

The capabilities of the new technologies also may foster teacher education. For example, a national digital library could offer video clips of teachers delivering virtually any kind of lesson imaginable (e.g., such as those produced for the Third International Mathematics and Science Study). Teachers should be able "to click on something and watch a person teach that concept," said Jenkins. "We have incredible talent in teaching. So many of the problems that we have in education, have been addressed or solved by someone. But, in too many cases, nobody else knows that a particular problem has been addressed someplace else."

Teacher education requires cultural and social changes as well as technological advances. For one thing, teacher education needs to become more coordinated. Today, professional development opportunities usually are disconnected, so that teacher education does not build on itself.

The cultural assumptions surrounding teacher education also need to change. "We still have the old turn-of-the-century factory view—that of the teacher isolated in the classroom," observed Kays. "Until we can get teachers who instead of teaching five or six or seven courses a day are only teaching four courses a day, or three courses a day, with time to collaborate, with time to go out and get this kind of information, very little will be done." At this point, says Kays, the Internet "is a wonderful resource if you are willing to spend 12 or 14 hours a day dedicated to what you love to do."

However, even if a national digital library were available to pre-college teachers, it would have little effect on the education that students receive in schools if teachers do not know how to use it.[17] The construction of such a library therefore highlights the importance of teacher education. Teachers need to know how to move from place to place within a library and gather information. If a particular hardware or software platform is needed to use a resource, they have to be able to accommodate those demands. "That's going to require training," said Labov, "and districts don't necessarily have the funds to do that."

[17] Two reports that were released several months after this workshop document the lack of training for both future (Moursund and Bielefeldt, 1999) and practicing teachers (CEO Forum on Education and Technology, 1999).

As in other professions, many current teachers are not comfortable with computer technologies and require much more than a list of directions to get started. As Roempler pointed out, “I've had people who don't even understand how a mouse works.” Some school districts are requiring that new teachers entering the system demonstrate competency in computer technologies.[18]

Although more teachers are learning to use computers on their own, specific incentives offer one way to get teachers up to speed with a particular technology. Some programs offer teachers the continued use of a computer after completing a training session. In other cases, summer programs can get teachers started with computers. Requiring teachers to use computers also can get results. “Some teachers will resist and resist using e-mail until that's the only way they can get information,” Jenkins pointed out. “Maybe the bulletin doesn't appear on paper anymore—if teachers want it, they've got to open up their computer. Or teachers can't turn in their attendance reports on a little slip anymore—they would have to turn on the computer and turn it in.”

Once teachers do get started, they tend to increase their use of information technologies. “It's like anything else,” said Davis, “you use what you need. Once they become comfortable with email and other activities they will then begin to find uses for the technology in their classrooms.” According to Horn, “Teachers have to start someplace. If it's something that can grow and become helpful to one teacher, it eventually will become helpful to many teachers.” Participants acknowledged that education in the use of computers and electronic communications needs to span the entire career paths of teachers, from pre-service education to the continuing education of veteran teachers. In colleges and universities, schools of education as well as arts and science faculty need to consider how to better integrate computers into the education of future teachers. Alternative certification programs for teachers also need to incorporate computer training. Because of teacher shortages in many parts of the country, many people now are being hired into teaching without the formal background usually required of new teachers, yet both these teachers and their more senior colleagues may need to know how to use a national digital library.

Funding and Control

Workshop participants viewed the source of funding for a digital national library as a major uncertainty. “Accessing the volumes we'd need for a good, intelligent, graphically rich environment takes a lot of money.” Masullo said. “Let me go farther than that. It requires a very large and steady infusion of dollars to sustain that kind of access.”

One possibility is that a national digital library would be funded entirely from public sources. The danger of public funding is that project money could be discontinued after five to

[18] For example, workshop participant Toby Horn pointed out that this requirement is now a part of the hiring record for teachers in the Fairfax County, VA school system.

ten years, leaving teachers without resources on which they may have come to depend. Support would therefore have to be ongoing, as, for example, is the case with government's support of the Smithsonian Institution.

Workshop participants also discussed several business models that might provide continuing, stable funding for a digital national library. One model is to charge teachers or schools for use of the library, although teacher Ghent-Paolucci pointed out that teachers are unlikely to be willing to pay more than a modest amount for such services. Another would be to charge for connect time or use, as with current long-distance services. But such charges are not a customary way of providing public services such as library services in this country. Participants emphasized that even modest charges to individuals would discourage utilization and could further exacerbate inequities in access to such resources.

Some participants suggested that a national digital library could very well establish its own model for continued support. “Nets can and frequently do encourage grassroots movements,” said Moses. “How? By allowing people to ‘end-run' around rigid institutions...Instead of looking through this little keyhole, people now have a whole new view of the world.” The economics of digital services also will change as today's bandwidth limitations to schools, businesses, and homes ease. Already, some schools offer their teachers free Internet access at home to make it easier to use digital services. If bandwidth increases without concomitant increases in charges, such access will be even easier to provide.

The issue of incentives for teachers to use and contribute to the library is an important one, according to several participants. For example, one way to encourage teachers to use a digital national library would be to link it to the credentialing process. “Right now the only ways to be able to improve your position that school districts recognize are: go through a university system and get credit, go to a conference, or publish a book or paper” said Horn. “If contributions to a digital national library were recognized and rewarded as professional accomplishments, teachers would have much greater involvement with the system.”

Related to the issue of funding are a number of questions surrounding control over the contents and operations of a digital national library that were also raised at the 1997 NRC workshop. Would a library be governed by the government or by a board of directors? Or would control be distributed, as is the case with the Internet today? Who would dictate the system standards to guarantee interoperability? And who would make decisions concerning what the library would contain or how materials are reviewed and cataloged?

VISIONS OF THE FUTURE

To summarize their deliberations, workshop participants devised the following objective for a national digital library that could be used by the pre-college community: Such a system should provide comprehensive resources for quality teaching and learning in science, mathematics, engineering, and technology. The participants also encapsulated their thinking about what would contribute to such a resource (Figure 1, page 19). Among the considerations that should guide the design and content of the library are the following:

- Connections to classroom practice and classroom settings — Information technology should be designed to facilitate teaching and learning by taking into account current and future physical settings in schools and developing curricula (e.g., those based on national and state standards).
- Evidence of what works in improving science, mathematics, and technology education for the pre-college grades — Continual assessment of whether the materials, tools, and other resources available to various communities of users are actually improving student learning.
- Connections to professional development—Materials and other resources that enable teachers to expand their knowledge, understanding, and appreciation of science, mathematics, and technology both for personal learning and for expanding their ability to teach these subjects effectively.
- Connections to educational standards and real world applications—Resources that enable teachers and students to explore the latest applications and implications of science, mathematics, and technology and to locate information about employing national and state standards of teaching and learning to their classrooms.
- Articulation among educational levels (such as between the content of AP courses and first-year college and university classes)—Resources that could be used by both high school and college faculty to make the transition between the pre-college and undergraduate years more seamless.
- Ties to student interests—Easy access to information that can be individualized to the interests and talents of different students while illustrating fundamental concepts in science, mathematics, or technology.
- Illustrations of best practice—Text, audio, video, and software tools that can demonstrate to new teachers and provide insight to practicing teachers about alternative ways to present information, concepts, and skills to students in a variety of learning settings and situations.

Despite the many questions that continue to surround a digital national library, workshop participants were extremely optimistic when asked to envision what might be expected in the foreseeable future. Lessons could be clearly tied to standards while still being able to meet the needs of different groups of students. Information would be connected across disciplines, allowing teachers and students to range further across the curriculum. Resources would be embedded within the research base on teaching and learning, so that students and teachers could take advantage of current best practices that are informed by scholarly research on improving education.

Teachers and faculty could communicate easily and quickly about issues of teaching and learning. Communities of teachers would form during pre-service education and remain intact throughout teachers' careers. Assessments would be available to measure students' increased interest and capabilities in science, mathematics, engineering, and technology as well as teachers' increased ability to produce those improvements.

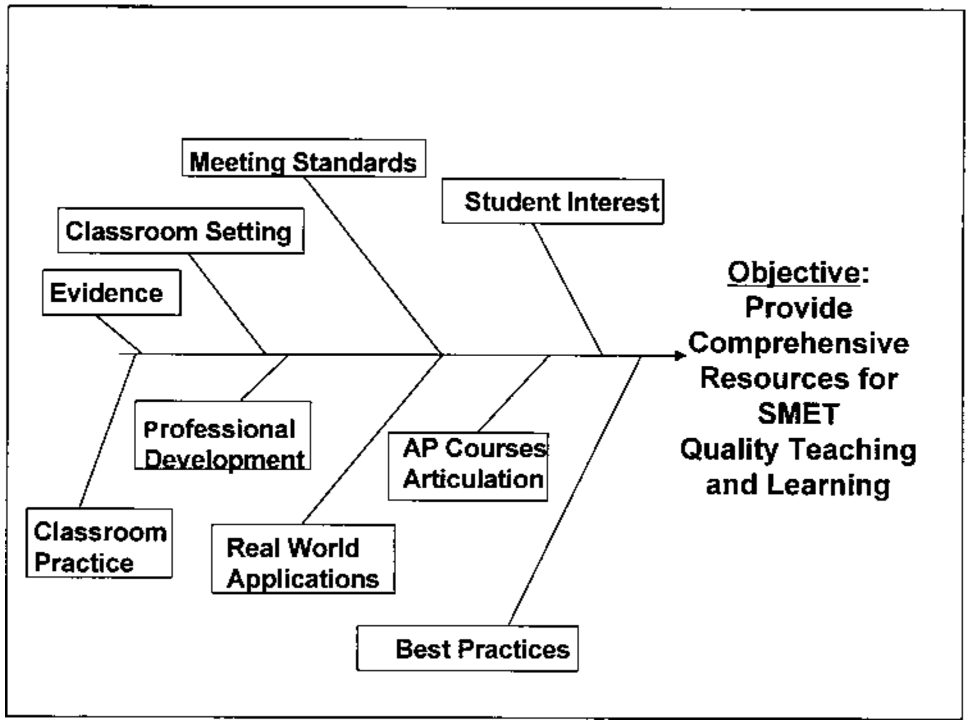

Figure 1: The primary objective of a digital national library for the K-12 community (to the right of arrow) and examples of the kinds of information, materials and tools that might be placed into this resource to reach the objective.

The challenge facing a national digital library is immense, said Wattenberg. It is no less than, first, to improve the quality of education and, second, to ensure that the highest quality education reaches every student. Yet the potential of a digital national library to fundamentally change the ways that science, mathematics, and technology are taught in the nation's schools and postsecondary institutions is sufficiently great to meet that challenge. Workshop participants look forward to seeing this vision of a digital national library that provides resources, materials, and connections among the science, mathematics, engineering, and technology communities realized as quickly as possible.

LITERATURE CITED

American Association for the Advancement of Science. 1993, *Benchmarks for Science Literacy.*Washington, DC: American Association for the Advancement of Science.

CEO Forum on Education and Technology. 1999. *Professional Development: A Link to Better Learning.* CEO Forum School Technology and Readiness Report. Washington, DC: CEO Forum on Education and Technology. Also available at: <http://ceoforum.org>

Moursund, D., and Bielefeldt, T. 1999. *Will New Teachers be Prepared to Teach in a Digital Age?: A National Survey on Information Technology in Teacher Education.*Santa Monica, CA: Milken Exchange on Education Technology, Milken Family Foundation.

National Council of Teachers of Mathematics. 1989. *Curriculum and Evaluation Standards for School Mathematics.*Reston, VA: National Council of Teachers of Mathematics.

National Research Council. 1995. *National Science Education Standards.*Washington, DC: National Academy Press.

National Research Council. 1998. *Developing a Digital National Library for Undergraduate Science, Mathematics, Engineering, and Technology Education: Report from a National Research Council Workshop.*Washington, DC: National Academy Press.

APPENDIX A

Executive Summary of Original Digital Library Report

DEVELOPING A DIGITAL NATIONAL LIBRARY ON UNDERGRADUATE SCIENCE, MATHEMATICS, ENGINEERING, AND TECHNOLOGY EDUCATION: EXECUTIVE SUMMARY*

A central role of the National Science Foundation (NSF) is to support the improvement of science, mathematics, engineering, and technology (SME&T) education for all students in the United States at all grade levels. In its quest to catalyze and sustain educational reform at the undergraduate level, the NSF issued a report in 1996 on the status of undergraduate SME&T education (National Science Foundation, 1996b). That report called for fundamental changes in the ways in which SME&T subjects are taught and urged the agency to sponsor the development of "a national electronic library for validating and disseminating successful educational practices" (National Science Foundation, 1996b, page 72) and to "provide specific problem training sessions for faculty across institutions, in topics such as how to do inquiry and collaborative learning in large 'lecture' classes, how to assess learning outcomes, and how to document learning gains at the departmental and institutional levels" (National Science Foundation, 1996b, page 72).

Digital libraries[1] are currently under construction for a number of scientific research communities with support from the NSF, the National Aeronautics and Space Administration (NASA), and the Department of Defense's Advanced Research Projects Agency (DARPA). The Library of Congress also is developing a digital library to disseminate its vast holdings more readily. Given the potential of digital libraries to provide rapid access to large amounts of information and the research base on digital libraries that these other projects already had

* Page numbers in this executive summary refer to those in the full report, National Research Council, 1998. *Developing a Digital National Library for Undergraduate Science, Mathematics, Engineering, and Technology Education: Report of a National Research Council Workshop.* Washington, DC: National Academy Press.

[1] Dr. Christine Borgman, UCLA, offered the following definition as determined by participants at the UCLA/NSF Workshop, "Social Aspects of Digital Libraries": "[Workshop participants] determined that digital libraries encompass two complementary ideas: 1. Digital libraries are a set of electronic resources and associated technical capabilities for creating, searching, and using information. In this sense they are an extension and enhancement of information storage and retrieval systems that manipulate digital data in any medium (text, images, sounds, static or dynamic images) and exist in distributed networks. The content of digital libraries includes data, metadata that describe various aspects of data (e.g., representation, creator, owner, reproduction rights), and metadata that consists of links or relationships to other data or metadata, whether internal or external to the digital library; and 2. Digital libraries are constructed— collected and organized— by a community of users, and their functional capabilities support the information needs and uses of that community. They are a component of communities in which individuals and groups interact with each other, using data, information, and knowledge resources and systems. In this sense they are an extension, enhancement, and integration of a variety of information institutions as physical places where resources are selected, collected, organized, preserved, and accessed in support of a user community. These information institutions include, among others, libraries, museums, archives, and schools, but digital libraries also extend and serve other community settings, including classrooms, offices, laboratories, homes, and public spaces." (Borgman et al., 1996) This report is available on line at http://www.gslis.ucla.edu/DL/UCLA_DL_REPORT.html.

generated, the NSF's Division of Undergraduate Education asked the National Research Council's (NRC) Center for Science, Mathematics, and Engineering Education (CSMEE) to undertake a study that would 1) explore the feasibility of establishing a digital National Library for undergraduate SME&T education and 2) examine various challenges that would have to be overcome in order to build a library that is both educationally innovative and cost effective.

In collaboration with the NRC's Computer Science and Telecommunications Board (CSTB), CSMEE responded to NSF's request by forming a project steering committee consisting of representatives from the NRC's four postsecondary boards and committees (Mathematical Sciences Education Board, Board on Engineering Education, Committee on Undergraduate Science Education, and the Committee on Information Technology). The Steering Committee, in turn, commissioned ten “white papers” from individuals with expertise in SME&T education, technological aspects of digital libraries, library science, and economic and legal aspects of this rapidly evolving area of knowledge and research. These commissioned papers (revisions of which are reprinted in Appendix A of this report) served as the basis for plenary and break-out discussions at a workshop that was held at the National Academy of Sciences on August 7-8, 1997. Some 50 guests from academe, digital library initiatives, private laboratories, private foundations, research and teaching libraries, and the commercial publishing sector participated in this workshop.

ISSUES CONSIDERED

The issues that these papers and workshop participants considered are diverse and exceedingly complex. They include the following:

Curricular, Pedagogical, and User Issues

(e.g., Who is the potential user population? What types of materials should be included? What impact can be expected?)

Logistic and Technology Issues

(e.g., What kinds of editorial oversight are needed? What kinds of technology are currently available to build such a national library (NL)? How can a multi-year project like this adapt to new technologies that may emerge?)

Economic and Legal Issues

(e.g., How can we estimate or measure the costs and benefits of establishing an NL? What are the long-term financial implications? How could intellectual property, copyright, and “fair use” issues be resolved?)

At the workshop, Steering Committee Chair Jack Wilson also charged participants with trying to arrive at answers to the following cross-cutting questions:

Is an NL a good idea for improving undergraduate SME&T education?

Is an NL a better idea than other initiatives that might compete for the same funds?

If the NSF does commit to supporting the proposed NL, then what kinds of information and issues will it need to consider so that the project can be undertaken efficiently and cost effectively?

Accordingly, this report provides a detailed summary of the presentations at the workshop and a synthesis of the discussions that were generated there. The report also identifies those issues on which workshop participants were able to reach substantial agreement and those which remained unresolved by the conclusion of the meeting. The report presents the conclusions of members of the Steering Committee who attended the workshop and provides a number of recommendations to the NSF from the entire Steering Committee about both the value and feasibility of proceeding with this project.

OVERVIEW OF CONCLUSIONS

The conclusions of the workshop are organized here by major issues addressed.

Users and Needs

These issues pervaded the entire workshop. A broad agreement developed that faculty engaged in SME&T education would be included among the primary users targeted by an NL. Workshop participants also concurred that the central focus of an NL should be to improve and enhance learning of SME&T.

Nevertheless, there was considerable divergence of opinion about the extent to which an NL also should provide learning resources directly to undergraduate students and possibly other users (e.g., advanced high school students, adults engaged in distance learning through a university program, lifelong learners seeking information on specific topics, or those wishing to increase their understanding and appreciation of SME&T in general). There also was a divergence of opinion about how often these “student users” would access an NL.

Most workshop participants agreed that the establishment of an NL could potentially be a useful tool for improving undergraduate SME&T education. However, some workshop participants noted that a large part of the SME&T teaching community has not yet felt a sense of urgency about the need for reform. Indeed, for the most part, participants believed that the workshop discussions had not made a convincing case that an NL was an essential component of SME&T education reform. However, some workshop participants and commissioned papers pointed out that, in addition to providing high-quality materials for improving learning of SME&T, an NSF-sponsored initiative to support an NL could have an important impact on undergraduate SME&T education by underscoring and showcasing the importance of educational reform in highly tangible ways. On the other hand, funds used to support an NL would then not be available to support other educational initiatives, and there is no current analysis available that indicates the relative efficacy of an NL compared to alternatives.

Because only a few science and mathematics teaching faculty and undergraduate students were present at the workshop (a list of workshop participants and their institutional affiliations is provided in Appendix C; biographical sketches of workshop participants are in Appendix D), it is not clear to what extent the proposed NL actually would be utilized by faculty to improve their teaching of SME&T courses or by other stakeholders of a larger NL. Input and advice from potential users also will be critical for designing and developing an NL's content.

Content

There was considerable discussion about what kinds of information the proposed NL should contain. Workshop participants agreed that an NL could offer a large variety of materials, such as digitized text (e.g., from professional journals, course syllabi, student works-in-progress, reports about the outcomes and evaluation of SME&T education projects that have been funded by NSF and other grantmaking agencies), videos and still images, instructional software and simulations, and anything else of relevance that could be stored digitally. However, there was little agreement about which classes of these materials an NL should make available, either immediately or in the future. In part, these disagreements were related to the issue of who the primary users of an NL will be. Thus, defining the intended audience for any NL initiative will aid in making decisions about its content. Discussion focused on several important issues related to content:

1. Should an NL commission and store discipline-based source content or serve primarily as a cataloging resource that electronically “points” users to information stored on other computers and hard copy? A broad agreement developed that, at a minimum, an NL should contain pointers to useful materials. Pointers are much less expensive to create and maintain than stored source content, more easily allow for contributions from a wider spectrum of interests and organizations in the SME&T community, and minimize current legal challenges related to intellectual property rights, copyright law, and licensing agreements. However, an NL could face several important constraints if it were to rely exclusively on the use of pointers rather than commissioning and storing at least some materials. Until consistently reliable software is available to enable an NL's registry to update the addresses of materials stored elsewhere on the Internet, tracking the location of materials will be problematic. An NL's ability to catalyze development of or to exert quality control over materials specifically suited to this medium could be very limited. Also, an NL's holdings should reach a “critical mass” of quality materials that will attract wide usership; whether the quality and quantity of materials currently on the Internet is sufficient to reach this “critical mass” in different subject areas must be determined.
2. Should an NL simply make materials available (either directly or by pointing to other Web sites), such as traditional libraries do now, or allow users to add materials to a library? Contributed materials might include such items as new teaching tools and modules or annotations (e.g., reviews, comments by users, supplemental information) about materials already available from an NL.

3. Who should exert editorial oversight of the proposed NL's contents? What types of standards should be established for accepting materials for an NL? Minimum standards and strategies for including materials and the level of editorial oversight would likely be very different if an NL were simply to point to other resources rather than storing and disseminating them directly to users. Different standards also would have to be developed for accepting materials that have undergone peer review vs. materials that have not been subjected to such scrutiny (e.g., course syllabi, courseware applications, annotations and discussions about other materials included in the proposed NL). The workshop participants broadly agreed that some mechanism for distinguishing formally reviewed from unreviewed material would be necessary, both from the standpoint of the user and for the credibility of the proposed NL itself.
4. Who should create content for an NL? Here there was fairly broad agreement that creators could include faculty, publishers, professional societies, and students. The issue of who creates content for an NL also relates to the issue of "critical mass." If the information in an NL is not sufficient in quantity or quality, user disappointment followed by disuse are likely consequences. All of these issues have implications for what materials are placed into an NL and how long they are archived.[2]
5. What kinds of tools will be needed to facilitate browsing and searching of an NL by users? Experience with currently available search engines for the Internet clearly indicates that simple keyword searches, though sometimes useful, are inadequate when searching through large volumes of information. Development of interactive, "intelligent" tools that facilitate searching for materials, especially those that have been designed to exploit an NL's specific electronic capabilities, should be an important component in any design of an NL for undergraduate SME&T education.
6. Is the proposed NL a library? Most workshop participants agreed that an NL for undergraduate SME&T education certainly would embrace many of the characteristics of traditional libraries. However, this resource also could incorporate many other features not found in traditional libraries, such as the capacity for the NL's users to add materials and to work interactively with and upgrade materials already in the NL. Thus, workshop participants suggested, and the Steering Committee concurs, that a better set of descriptors be devised to reflect more accurately this resource's vision and objectives and to convey better to users how it might be utilized.

Economic and Legal Issues

In addition to focusing on the potential value or desirability of an NL for undergraduate SME&T education, the workshop also addressed a number of economic and legal issues. These

[2] In this report, "to archive" and "to serve an archival function" mean to preserve in readable form over the long term any material determined to have enduring value. "To store" and "to preserve" are used in this report in a technological sense, as in to save copies off-line of material no longer in active use but possibly desirable at some future date

topics were considered by workshop participants primarily in the context of the implementation and deployment of this resource. The following issues were raised.

1. Economic issues: While government agencies and private foundations might provide key start-up funding for an NL, workshop participants agreed that this resource would eventually need to become financially self-sustaining. However, there was no general agreement about how best to address questions of economic viability and sustainability.
2. Legal issues: Workshop participants identified a number of legal issues that would need to be solved before the proposed NL could become operational. These include

- Intellectual Property (IP). IP issues in the context of an NL are similar to those that any online provider of content faces. However, inclusion of some types of material (e.g., course notes) may not be as problematic as other materials because remuneration to the authors or developers is not necessarily involved.
- Liability. NL materials that involve some potential risk to users (e.g., instructions for performing undergraduate laboratory exercises) may involve liability for those responsible for administering the proposed NL initiative or for the authors and creators of materials to whom an NL points.
- Privacy. To the extent that students use materials or information found in an NL (e.g., an online diagnostic test), well-meaning faculty may be interested in the extent and nature of such usage. Obtaining such information might impinge on students' expectations for privacy.

Workshop participants concluded that these issues could not be solved independently for the proposed NL. Rather, a regime of general law and practice will evolve as online publishing and dissemination of information becomes more extensive. An NL for undergraduate SME&T education will have to be flexible enough to accommodate a wide range of possible legal regimes and challenges.

3. Technology issues: Workshop participants discussed many technology-related issues, including

- The need for an NL to be oriented to satisfying user needs rather than to being a vehicle for advancing the creation of technology or research about digital libraries. Any technologies employed by an NL also should be developed and deployed to accommodate the needs of users. Associated with this requirement, some workshop participants questioned the conventional wisdom of making the proposed NL available exclusively via the Internet. Because some institutions of higher education in the United States and other parts of the world do not now enjoy access to the Internet and others have only limited access through data lines that would require too much time for the downloading of large applications or data sets, important issues of equity and access must be considered carefully and addressed. Other formats, such as CD-ROM sets, might be considered as components of vehicles for disseminating information from any NL initiative (although interactivity could be compromised compared to access to the Internet).

Workshop participants also noted that the development of Internet II could possibly restrict access to an NL only through selected colleges and universities.[3],[4] Again, equity of access should be an important consideration in any discussions of delivery systems for this NL.

- An NL for undergraduate SME&T education should employ technologies that are adaptive, flexible, and responsive to unforeseen user needs and problems. New applications and modules should be designed to operate with software that is widely available for other applications (e.g., commonly used spreadsheets). This design would reduce the time required for users to learn how to work with such materials. An NL initiative also will need to deal with content prepared to run on older computers and software platforms that may be incompatible with newer hardware and software platforms.
- Technology employed in the proposed NL should be developed with advice and oversight from the professional communities who are most knowledgeable about how people both organize and use information: librarians and social and behavioral scientists. Without these informed perspectives, an NL is not likely to optimize opportunities for teaching and learning.

STEERING COMMITTEE RECOMMENDATIONS

Workshop participants generally agreed that the idea of an NL for SME&T education was sufficiently promising that the NSF should pursue it further, and the Steering Committee concurs. Although workshop participants did not agree on specific next steps, the Steering Committee makes the following recommendations based on information in the commissioned papers and presentations and discussions at the workshop to guide the NSF's planning for an NL initiative and its issuance of one or more request for proposals (RFPs). The Steering Committee recommends that these steps be acted upon sequentially. The recommendations that are

[3] President William Clinton's announced goals for the Next Generation Internet initiative are as follows: 1. Connect universities and national labs with high-speed networks that are 100 to 1,000 times faster than today's Internet. These networks will eventually be able to transmit the contents of the entire Encyclopedia Britannica in under a second; 2. Promote experimentation with the next generation of networking technologies. For example, technologies are emerging that could dramatically increase the capabilities of the Internet to handle real-time services, such as high-quality videoconferencing; and 3. Demonstrate new applications that meet important national goals and missions. Higher speed, more advanced networks will enable a new generation of applications that support scientific research, national security, distance education, environmental monitoring, and health care. Smith and Weingarten, 1997.

[4] A reviewer of this report, who must remain anonymous under the Report Review Guidelines of the National Research Council, wrote to disagree with the workshop discussion regarding lack of wide accessibility to Internet II: This person indicated that his institution has had access to the Very Broadband Network Service (VBNS), the precursor of Internet II, for some time. The institution has a switch that routes outgoing messages to the VBNS or the Commodity Internet (Internet I), depending on the destination. No one on the Commodity Internet has had problems reaching this reviewer or others at this university. The reviewer acknowledged that there may be issues of performance between Internet I and II, particularly if streaming audio or video applications are developed, but this reviewer does not believe that access will be an issue.

summarized below parallel the discussion in the “Synthesis and Conclusions” sections of the report, and readers should consult that section for additional details. The following text is cross-referenced to relevant text in that section.

1. Clarify the potential customers of an NL for undergraduate SME&T education (page 47)

1.1 Because workshop participants were unable to delineate the stakeholders or to specify the content for this proposed NL, the NSF should do so. The level of funding that the agency can devote to this project may dictate the breadth of the proposed NL's users, and that, in turn, may help with content decisions. However, the Steering Committee recommends that, prior to making final decisions about this issue, the NSF should make a concerted effort to bring together in a series of focus groups representatives from all communities that might be an NL's likely users and service providers. Focus groups should be small and should be structured to encourage participants to discuss freely 1) their requirements for resources and tools that would help them improve teaching and learning of undergraduate SME&T, and 2) the ways in which the digital National Library could address those requirements. At a minimum, participants in these focus groups should include

- College and university SME&T faculty from all types of postsecondary institutions, including two-year colleges, undergraduate liberal arts colleges, predominantly undergraduate comprehensive universities, and research universities.
- College and university SME&T faculty at different stages of their academic careers.
- College and university faculty involved with research and practice in science and mathematics education, including the preparation of future K-12 teachers.
- SME&T faculty from middle- and high-schools across the United States.
- Undergraduate students from different types of colleges and universities. This group should include both “traditional” and “non-traditional” students.
- Graduate and postdoctoral students who are likely to enter careers in academe also should be consulted since they will define future needs of faculty.
- Librarians.
- Social and behavioral scientists with expertise in organizational constructs and in the ways in which people learn new information.
- Computer and information system specialists with specific experience with digital libraries.
- Directors of college and university information technology services.
- Representatives from the commercial publishing sector.

- Representatives from professional SME&T societies.
- Representatives from the private non-profit sector, such as foundations.

1.2 The Steering Committee suggests that two different types of focus group meetings be held. Some focus groups should concentrate on receiving input from single communities, especially SME&T faculty and students. Others should involve people from many or all of the aforementioned sectors in crosscutting sessions, with the primary objectives of having convenors listen and respond to the ideas and expressed needs of potential users.

1.3 The Steering Committee recommends that NSF also might employ the services of one or more professional organizations to organize these focus groups, to facilitate discussions within the groups and to prepare an independent assessment of user needs and desires based on the group discussions.

2. Articulate priorities for content, technological considerations, and economic and legal models before committing to the establishment of an NL (page 48)

The Steering Committee can offer no specific recommendations about whether the proposed NL should commission the creation and storage of materials vs. developing a sophisticated system of pointers to materials that reside and are maintained elsewhere. Differences in cost between the two systems, evolving legal precedents with respect to copyright and fair use of materials, and the emergence of new technologies that may overcome some of the limitations of pointing to information stored elsewhere all must be factored into the final structure of an NL. Moreover, these parameters are likely to change during the development phase of the project. Ongoing advice from appropriate experts in all of these fields is warranted if the project proceeds.

2.1 The Steering Committee recommends that the proposed NL be viewed primarily as a resource for improving and inspiring learning of undergraduate SME&T rather than merely as a means to promote more effective teaching of these subjects. If an NL is to be a central component of current efforts to reform and improve undergraduate SME&T education, it must offer more than teaching tools alone. The NSF should appoint a Board of Overseers consisting of acknowledged experts in SME&T education, library sciences, and digital libraries that is charged to work with a broad spectrum of intended users and the other stakeholders before decisions are made about what kinds of materials should be placed into the proposed NL. If an NL initiative cannot afford to support all areas of SME&T, then the Board should decide on the initial areas of focus and look to expand coverage as the project develops.

2.2 Steering Committee members also agree with many workshop participants and recommend that an NL should strive to focus on collecting or pointing to materials that either are inaccessible through other media formats or are so innovative that they are unlikely to be commercially available or viable in the short-term. Because a “critical mass” of materials is vitally important to the success of an NL, the acquisition of such innovative new materials will likely need to be balanced with more traditional materials, at least initially.

2.3 The Steering Committee recommends that the NSF emphasize involvement by professional SME&T societies in developing content that could be appropriate for an NL. Many of these organizations already have produced materials that might be incorporated into an NL at little or no cost. By promoting the development of these kinds of teaching and learning tools and by officially recognizing their members who do so, professional societies could become key catalysts in changing the culture of higher education to embrace as legitimate scholarly activities the promotion and evaluation of teaching and the promotion of effective learning by students.

2.4 The Steering Committee recommends that an NL should provide information about and access to projects in undergraduate SME&T education that the NSF and other agencies have supported financially.

2.5 The Steering Committee recommends that the NSF also seek a new, more encompassing descriptor for this project. Workshop participants recognized, and the Steering Committee concurs, that "Digital National Library" or "National Library"—the terms that have been most commonly used to describe this entity—may be more confusing than enlightening to anyone who envisions the potential stakeholders in this project and the services it may provide. Any NL initiative is likely to transcend the functions of many conventional libraries. A more appropriate descriptor might help to focus the higher education community on the need for such a resource and its importance.

3. Develop and issue one or more RFPs to establish an NL for undergraduate SME&T education

As the NSF receives additional input from stakeholders about the goals of and need for an NL (via Recommendations 1 and 2), the scope and potential cost of the project should become clearer. During the workshop, Steering Committee Chair Jack Wilson charged participants with trying to arrive at answers to the following major crosscutting questions: 1) Is an NL a good idea for improving undergraduate SME&T education and 2) Is an NL a better idea than other initiatives that might compete for the same funds? If the NSF is convinced on the basis of its explorations that it can answer these questions in the affirmative, then the question of how to implement this project should become the central focus. Options for proceeding at that point would include

Option 1: Undertaking a single, large initiative that would result in an operational NL within several years.

Option 2: Undertaking several smaller initiatives for shorter periods of time (12-24 months). These initiatives might be competitive and operate independently of each other or they might be components of some larger cooperative agreement. These various models for establishing an NL could then be evaluated against each other, with a final coordination of best practices that might lead to a single, integrated project.

3.1 Given the tremendous complexity of this project and the number of communities that must be directly involved if it is to have any chance for success, the Steering Committee recommends that NSF consider adopting Option 2. Steering Committee members envision that the smaller initiatives suggested in Option 2 might be incorporated into a program similar to those that the NSF's Division of Undergraduate Education has sponsored in recent years to change the ways in which chemistry and calculus are taught. Optimally, this new initiative would incorporate many similar components, including those delineated in Recommendations 3.2 and 3.3 below.

3.2 The Steering Committee recommends that the NSF, in following through with Recommendation 3.1, should develop an RFP articulating the need for and issues involving the establishment of an NL as outlined in this report. The RFP would encourage diverse groups of stakeholders to focus on some subset of the issues. Collaboration among stakeholders and interdisciplinary approaches to address the questions posed here would be encouraged. Preproposals could be sought, with funds then awarded to successful groups to encourage them to develop full proposals. Depending on the funds available, the NSF might then award larger contracts to one or more groups to tackle specific issues or sets of issues. Each of these final awardees would be expected to inform each other of their progress and problems through routine communications, reports, and through meetings of teams convened on a regular basis (at least annually).

3.3 Because the central concern of workshop participants was to define the users of and the need for an NL for undergraduate SME&T education, the Steering Committee recommends that RFPs for preproposals not be formulated until the NSF sponsors the focus groups described above. Feedback and evaluation of information from these groups of users and providers could then serve as the basis for constructing RFPs that would help eventual awardees to address specifically the established needs and requirements of potential NL users.

APPENDIX B

Workshop Participants

Lee Jenkins (Workshop Facilitator) Superintendent Enterprise School District Redding, CA

Donna Davis Technology Coordinator District of Columbia Public Schools W.B. Patterson Elementary School Washington, DC

Julie Ghent-Paolucci Biology & Anatomy/Physiology Teacher Richard Montgomery High School Rockville, MD 20852

Toby M. Horn Science and Technology Division Manager Thomas Jefferson HS for Science and Technology Alexandria, VA

Vernon Kays (Representing the American Mathematical Association of Two-Year Colleges) Richland Community College Decatur, IL

Miriam Masullo Director of Educational Technology National Action Council for Minorities in Engineering New York, NY

Kurt D. Moses Vice President & Director, Systems Service Division Academy for Educational Development Washington, DC

Kimberly Roempler Associate Director for Instructional Resources Eisenhower National Clearinghouse Columbus, OH

James Stith Executive Director American Institute of Physics College Park, MD

Keith Stubbs Director Division of Resource Sharing and Cooperation National Library of Education U.S. Department of Education Washington, DC

NRC/NAS STAFF

Rodger Bybee Executive Director Center for Science, Mathematics, and Engineering Education

Joan Ferrini-Mundy Associate Executive Director Center for Science, Mathematics, and Engineering Education

Brad Findell Program Officer Center for Science, Mathematics, and Engineering Education

Donna Gerardi Director NAS Office on the Public Understanding of Science

Terry Holmer Senior Project Assistant Center for Science, Mathematics, and Engineering Education

Jay Labov Project Study Director, Center for Science, Mathematics, and Engineering Education
Harold Pratt Senior Staff Officer Center for Science, Mathematics, and Engineering Education
Jan Tuomi Senior Staff Officer Center for Science, Mathematics, and Engineering Education

NSF STAFF (OBSERVERS)

Katylee Hoover Division on Undergraduate Education
James Lightbourne Division on Undergraduate Education
Joan Prival Division on Undergraduate Education
Frank Wattenberg Division on Undergraduate Education

*** Biographical sketches of invited workshop participants are found in Appendix C (page 34)**

APPENDIX C

Biographical Sketches of Digital Library Workshop Participants

Donna Davis is a technology coordinator with the District Of Columbia Public School System. Donna has worked as a technology coordinator for the past 6 years. Her work includes training teachers on successful integration of technology into the curriculum, writing technology integrated curriculum for science and other areas and working with businesses and other community partners to bring technology to schools. Donna has an undergraduate degree in Elementary Education and master's degrees in Early Childhood Education and Guidance and Counseling. She has had extensive training in computer science, Over the past three years she has worked in over fifty District of Columbia Public Schools assisting with the effort to get schools connected to the Internet. Philadelphia Public School System, EarthWatch International, Bell Atlantic and Carnegie Institute are just a few of the organizations she has worked with on technology training and technology curriculum writing. Donna is one of the founders and on the board of directors of Tech Corp-DC.

Julie Ghent-Paolucci is an anatomy/physiology and biology teacher at Richard Montgomery High School in Montgomery County, Maryland. She has taught high school biology classes of all levels, from ESOL to AP/IB, for 15 years. She is currently working on curriculum development to incorporate various technologies, including appropriate software and Internet usage, as well as biotechnology and virtual labs. Julie has a BS in zoology and a BS in secondary science education from the University of Maryland. She is a former Howard Hughes Medical Institute (HHMI) intern, and has done graduate research in curriculum development for high school biology.

Toby Horn is Division Manager for Science and Technology at Thomas Jefferson High School for Science and Technology in Alexandria, VA. A scientist who became a precollege teacher, Dr. Horn has expertise in issues associated with student academic preparation for school-to-work through mentorship, teaching science through doing science, and with the preparation and practice of science teaching. She was invited by the Howard Hughes Medical Institute (HHMI) to serve as a panelist in a discussion on “Rethinking Science Teacher Training” at the recent meeting of Project Directors for HHMI undergraduate education initiatives.

Lee Jenkins has served as a teacher, administrator, college professor and superintendent during his 32 years in public education. His interest in mathematics education began in the 1960's when he was introduced to mathematics manipulatives. His publications include ten books for teachers in the use of various manipulatives. Currently Dr. Jenkins is a frequent speaker on quality management at regional and national meetings. He addressed audiences at the last four Governors' National Quality and Education conferences sponsored by Colorado, Minnesota, New Mexico and Virginia. His latest publication, from the American Society for Quality Control, is entitled *Improving Student Learning: Applying Deming's Quality Principles in* Classrooms. The book chronicles his years of learning and applying quality principles within the Enterprise School District since 1990.

Vernon Kays is an Assistant Professor of Mathematics, Richland Community College, Decatur, Illinois. Dr. Kays has been actively involved with the work of AMATYC, NCTM, MAA, ISMAA, IMACC, and ICTM. Chair Electronic Services Committee and Vice Chair Foundations Committee AMATYC. Co-Chair IMACC Annual Conference and Chair IMACC Web site and data base committee. Graduate Student at University of Illinois Champaign-Urbana in the Community College Leadership Program. Master of Mathematics - Statistics from University of Illinois - Springfield. Taught for four years in middles schools as a mathematics and science teacher. Received award from INPUT for adapting a high school geometry course for community colleges using technology and collaborative learning. Dr. Kays also has been developing Tech-Prep connections between local high schools and the community college.

Miriam Masullo is a native of Cuba, who arrived the USA in the early 60's as a child refugee and lived and attended school in the African-American section of Harlem in New York City. She obtained all her academic degrees by attending The City College of New York (CCNY) as an evening student while working full time and raising a family as a single parent.

She received a bachelor's degree, majoring in Engineering Science, Architecture and English Literature, two Masters degrees, in Computer Science and Philosophy, and a Ph.D. in Computer Science for her interdisciplinary research with the Departments of Computer Science and Educational Psychology, from The City University of New York.

She is now a Research Staff Member (RSM), the most prestigious research position at the Thomas J. Watson Research Center, IBM's world-class Yorktown Heights Research Center. She came to this position 14 years ago, with a long held personal interest in education and 16 years of experience in both systems analysis and network engineering from the telecommunications industry.

Dr. Masullo serves in the New York State Curriculum and Assessment Committee for Math, Science and Technology, and has represented IBM Research at the National Science Education Standards effort sponsored by the National Research Council, and has participated in National Research Council initiatives relating to resources for science education. More recently she participated in the National Research Council workshops on Digital Libraries and undergraduate engineering education.

She is currently on faculty loan assignment from IBM to the National Action Council for Minorities in Engineering (NACME), as Director, Educational Technologies.

Kurt D. Moses, Vice President and Director, Systems Services Division, Academy for Educational Development has been working in educational reform for both K-12 and tertiary education for the last 25 years. During his work in the U.S. as well as with 38 countries overseas, he has encountered substantial problems, particularly in science and mathematics, with access to current bibliographic resources, and adequate support to make new knowledge available, even to researchers. He has been involved with national efforts in seven countries to upgrade national library capacity, and recently in Mexico with several initiatives aimed at public university access to scientific material. AED itself has supported several international initiatives to digitize key materials for wider distribution. Mr. Moses is a graduate of Stanford University and the University of Chicago.

Kimberly S. Roempler is the Associate Director for Instructional Resources for the Eisenhower National Clearinghouse for Science and Mathematics at The Ohio State University. She has a B.S. in Zoology and Chemistry, a M.A. in Science Education, and completed her doctorate in Science Education at OSU. Before accepting the Associate Director position, she was the Science Resource Specialist at ENC, taught science methods courses, supervised student teachers, developed inservice programs for teachers on the topics of authentic assessment and the Ohio Competency-Based Science Model, and was an evaluator for Project Discovery (Ohio's State Systemic Initiative Project) and the Buckeye Assessment Teams for Science (BATS) project. She taught science for ten years at the high school and community college levels before coming to ENC. As Resource Specialist, she worked daily with science educators, helping them learn about the resources available to them, both real and virtual.

James H. Stith is the Director of Physics Programs for the American Institute of Physics. His Doctorate in physics was earned from The Pennsylvania State University and his Master's and Bachelor's degrees in physics were received from Virginia State University. A physics education researcher, his primary interests are in Program Evaluation and Teacher Preparation and Enhancement. He was formerly a Professor of Physics at The Ohio State University and spent 21 years on the faculty of the United States Military Academy at West Point. He has also been a visiting Associate Professor at the United Air Force Academy, a Visiting Scientist at the Lawrence Livermore National Laboratory, a Visiting Scientist at the University of Washington, and an Associate Engineer at the Radio Cooperation of America. He is a past president of the American Association of Physics Teachers, a Fellow of the American Association for the Advancement of Science, a Fellow of the American Physical Society, a Chartered Fellow of the National Society of Black Physicists, and a member of the Ohio Academy of Science.

Keith Stubbs' current responsibilities as Director of the National Library of Education's Resource Sharing and Cooperation Division include the U.S. Department of Education's Web site, the Education Resources Information Center (ERIC) and its 30+ Web sites (which include AskERIC and the National Parent Information Network), and plans for a resource sharing network for educational libraries and information providers. Mr. Stubbs initiated ED's Internet presence in 1992, launched ED's Web site in March 1994, led an award-winning Web redesign and wrote ED's Web Server Standards SME&T Guidelines in 1995, represented ED on the World Wide Web (WWW) Federal Consortium 1995-1998, and recently conducted one of the first OMB-sanctioned Internet customer surveys. He co-chairs ED's Internet Working Group and represents ED on the interagency Federal Resources for Educational Excellence (FREE) initiative. Currently he is directing several Internet indexing, cataloging, and searching projects including the Gateway to Educational Materials (GEM) and ED's Cross-Site Indexing Project.

APPENDIX D

Workshop Agenda

WORKSHOP ON THE USES OF A DIGITAL NATIONAL LIBRARY FOR UNDERGRADUATE SCIENCE, MATHEMATICS, ENGINEERING, AND TECHNOLOGY EDUCATION BY THE K-12 SCIENCE AND MATHEMATICS EDUCATION COMMUNITY

Mathematical Sciences Education Board Center for Science, Mathematics, and Engineering Education National Research Council

September 24-25, 1998

Cecil and Ida Green Building, Room 118

2001 Wisconsin Ave., NW

Washington, DC

Thursday, September 24:	**Meeting the needs of users of the digital national library for undergraduate SME&T education from the K-12 mathematics, science, and technology communities**
8:15 AM	Breakfast
9:00 AM	Welcome and Introductory Remarks: Lee Jenkins, Workshop acilitator Rodger Bybee, Executive Director, CSMEE Frank attenberg, NSF Program Officer
9:45 AM	Overview and discussion of the August 1997 Workshop and the Report, *Developing a Digital National Library for Undergraduate Science, Mathematics, Engineering, and Technology Education*[1] Jay Labov, Responsible Staff Officer for the NRC's Digital National Library Workshops and reports
10:30 AM	Break
10:45 AM	**Uses of a Digital National Library for Undergraduate SME&T education by the K-12 community - Topic 1:** As a potential user (teacher, learner, or teacher educator) of a digital national library for undergraduate SME&T education, what would have to be available in this facility, both in terms of content and services, ***for you to initially log into this resource?***

[1] All workshop participants received a copy of this report. It is also available on-line in HTML format at the website of the National Academy Press: **http://www.nap.edu/readingroom/enter2.cgi?ED.html**

12:30 PM	Lunch. Optional viewing of Part 1 of the new 2-hour PBS series, *net.Learning*
1:45 PM	**Uses of a Digital National Library for Undergraduate SME&T education by the K-12 community - Topic 2:** As a potential user (teacher, learner, or teacher educator) of a digital national library for undergraduate SME&T education, what would have to be available in this facility, both in terms of content and services, ***for you to use it consistently for your teaching or learning?***
3:15 PM	Break
3:30 PM	**Concurrent Sessions:** **Topic 3: Uses of a Digital National Library for Use by People in Pre- and In-service Teacher Education Programs (Green 127)** What content, services and features should be incorporated into a digital national library for undergraduate SME&T education ***to best serve the curricular and professional needs of future teachers and those teachers involved with in-service programs in mathematics, science, and technology?*** **Topic 4: Uses of a Digital National Library by Professional Organizations for Teachers** What content, services and features should be incorporated into a digital national library for undergraduate SME&T education to best serve the needs of ***professional societies and organizations for teachers?***
5:00 PM	Reports from Breakout groups for Topics 3 and 4
5:40 PM	Adjourn for the day. Dinner on your own (NRC staff will assist those participants who wish to meet together for dinner at a local restaurant in making arrangements and reservations)

Friday, September 25:	**Materials and Resources that the K-12 mathematics, science, and technology education communities can provide to a digital national library**
8:00 AM	Breakfast and optional viewing of Part 2 of the new PBS series, *net.Learning*
9:15 AM	Overview of NRC-sponsored initiatives in mathematics education and science education: *Curriculum Materials for Teacher Professional Development and the World Wide Web* *Project RISE (Regional Initiatives in Science Education)* *Beyond Discovery*
10:15 AM	Break
10:30 AM	**Topic 5: What kinds of content, services, and other resources are currently available in the K-12 mathematics, science, and technology education communities that should be made available for use in a digital national library for undergraduate SME&T education?**
12:15 PM	Lunch
1:00 PM	Review of all discussions, areas of consensus, ideas to be presented in the workshop report to the National Science Foundation. Comments on*net.Learning* Final comments and instructions
2:30 PM	Adjourn