NSF Rethinks
Its Digital Library

A $175 million investment has fostered collaboration and created vast amounts of material. But the digital world is changing

THE WEB IS A DOUBLE-EDGED SWORD FOR TEACHERS. Linda Lai has seen it deliver wonderful answers to the toughest questions posed by her third- and fourth-grade students at Edith Bowen Laboratory School in Logan, Utah. But separating the wheat from the vast amount of chaff on the Web takes time. Lai also worries that her students may be exposed to inappropriate material as they search for knowledge.

Mimi Recker, a professor of instructional technology at Utah State University in Logan, which runs the kindergarten through grade-5 lab school, knows that the Web poses many challenges for teachers. That's why she asked the U.S. National Science Foundation (NSF) to fund development of a Web-based tool to help teachers find, manage, and

manipulate high-quality educational materials for use in the classroom. The software, called Instructional Architect (IA), is one of hundreds of research projects funded by NSF's National Science, Mathematics, Engineering, and Technology Education Digital Library (NSDL) program.

NSDL was launched in 2000 to help scientists and science educators tap into the rapidly expanding online world. Since then, the foundation has spent about $175 million "to provide organized access to high quality resources and tools that support innovations in teaching and learning at all levels." In practice, that has meant three things: creating and maintaining a Web site (nsdl.org) with a vast assortment of peer-reviewed materials, including lesson plans, videos, lectures, examples, and teacher guides; providing support for more than a dozen disciplinary

and sector-based portals, called Pathways, that offer suitable content to NSDL; and funding individual research projects, such as IA, that are aimed at helping researchers and educators make better use of online learning. [AAAS, which publishes *Science*, has received $5.3 million since 2000 to oversee the BiosciEdNet (BEN) Pathway.] The money also goes toward administration, outreach, and the support of a global community of users.

Although NSDL has always focused on education, precollege classroom teachers are only one of many audiences. In fact, the thrust of NSDL in its early years was to help the research community make available something—high-quality educational materials—that by and large didn't exist.

Because NSDL serves several different purposes, the payoff from NSF's investment, which has averaged almost $18 million a year (see graph, p. 57), has been hard to quantify. Its biggest advocates admit that relatively few educators and researchers have even heard of NSDL, much less visited the Web site or contributed material. It's proven to be no match for Google as a search engine for finding good sites. And there's no evidence to date that NSDL has improved student learning.

Although NSF officials insist that NSDL has been a success, the agency is in the process of reducing its support for digital libraries. Last year, the initialism NSDL was redefined as the National Science Distributed Learning program and subsumed under a new, broader cyberlearning initiative for which digital libraries are only a small component. In September, NSF cut its support to the organizations that manage NSDL by more than half and described the new round of funding as a "ramp-down … toward self-sufficiency." The consortia operating the various Pathway portals say they don't expect to get another bite of the apple. In 2007, NSF ended its funding of DLESE, a digital library for earth system education that is separate from NSDL but serves as an informal pathway for the earth sciences community (see sidebar).

Those in the trenches remain committed to making digital libraries an integral part of science education. But they face serious obstacles. Lai, who began teaching in 1971 and who admits that she's "technology challenged" by the profusion of communications devices now available, says she's found IA very user-friendly. "The site is easy for my kids to access, and it's very safe," she says. Lai prefers IA (ia.usu.edu) to the school's Web site, for which she must give an instructional aide a list of URLs and which allow no supplemental materials. "And I can do IA from home," she adds.

So how often do Lai and the other teachers at Edith Bowen, all of whom were trained on IA several years ago, use this powerful new online tool? Recker has found that only 20% of teachers in one study were still using IA 1 year later, and Lai and her colleagues are no exception.

"I haven't used it this year," Lai confesses. "My third graders are just learning how to use the laptops" that are kept in the school's media lab and carted around to classrooms as needed. "And I don't know how many [of the other teachers] still use it. There's so much else that we're expected to be doing, we don't really talk about IA."

Promise and reality

NSDL was launched in the waning days of the Clinton Administration, at the height of the dot-com boom, when expectations about the Web's potential were sky-high. One leading online policy guru, Thomas Kalil, then of the National Economic Council (and now a member of the transition team for President-elect Barack Obama), wrote in 1996 about the need to "leverage cyberspace" for economic growth. NSDL was seen as a way to do that in the realm of education, and Kalil and other White House officials promised that it would improve student performance,

New Landscape for the Earth Sciences

A digital library for the earth sciences community and by the community is now also *of* the community.

Four years before the U.S. National Science Foundation (NSF) launched the National Science Digital Library (NSDL) (see main text), leaders in the earth sciences community began planning what would become DLESE (Digital Library for Earth System Education). In 2002, NSF took the plunge, making a 4-year award to the University Corporation for Atmospheric Research (UCAR) to operate the distributed, community-based library of materials for undergraduate education and research. But in 2005, after getting a scathing report from a visiting committee on how NSF's $21 million investment had been managed, NSF decided to phase out its support. After much soul-searching, a slimmed-down DLESE found a home in 2007 within UCAR's National Center for Atmospheric Research in Boulder, Colorado, where it is now part of NCAR's library.

From the start, DLESE had twin goals: to unite earth and environmental scientists and to improve how those disciplines were taught, including the research component. In addition to vetting material for the library to assure high quality, researchers hoped DLESE would be their online watering hole, a place to foster collaborations and share their knowledge. But the NSF visiting committee found that DLESE's horizontal management structure actually inhibited good communications and that the sum of its various parts added up to less than the whole. "DLESE cannot be all things to all groups. … More is not always better," its report concluded. The program's fiscal stewardship was another problem. "Even with the documentation provided [us], we still have almost no idea how $21 million have been spent over the past 5 years," the committee noted.

Christopher Maples, a paleontologist and former NSF program officer who chaired the panel, acknowledges that "we were pretty tough on them." But the report also lauded DLESE for taking "a terrific, creative idea" and proving that it is "both promising and deserving." Maples, who this fall became president of the Oregon Institute of Technology in Klamath Falls, says "I haven't followed them since our report. But I'm glad to hear that they've landed on their feet."

Jill Karsten, program director for education and diversity within NSF's geosciences directorate, certainly agrees. She says that DLESE's "soft landing" is exactly what the foundation hopes will happen to worthy projects after their NSF funding runs out. (DLESE was supported largely by the geosciences directorate, which also funds NCAR, rather than the education directorate, which has funded NSDL.)

But Mary Marlino, DLESE's longtime director and now head of the NCAR library, sees the transition a bit differently. In addition to laying off staff, she had to jettison several community-based activities and outreach efforts. "We're at maintenance level," she says. "It's no longer DLESE on steroids. But we've survived, and we're moving forward."

DLESE initially targeted undergraduates and those who teach them, Karsten says, but it has gradually moved into elementary and secondary schools. In one such project, DLESE worked with middle and high school earth science teachers to prepare electronic "teaching boxes" for the classroom. "In the early days, we thought that access would be the ticket," says Marlino. "But now we realize teachers need to understand the resources in context and how to use them."

Earth science teachers will have to do it on their own, however. The instructional units, on topics from weather to plate tectonics, are online and ready to use (teachingboxes.org/). But after the loss of NSF funding, Marlino says there are no plans to develop any more boxes. **–J.D.M.**

A Nobelist's Passionate Pursuit of Excellence

In its role as a collection of collections, the National Science Digital Library (NSDL) offers more than 1.5 million resources to science educators. But even that impressive figure doesn't capture the work of everyone who is generating serious online content. One academic who operates outside NSDL's network is Harry Kroto, 1996 chemistry Nobelist for his co-discovery of fullerenes.

Kroto, who retired from the University of Sussex in the U.K. and moved in 2004 to Florida State University in Tallahassee to focus on science education, believes that it's possible to produce high-quality materials without following NSDL's protocol of first putting everything under a disciplinary microscope. Instead, he argues that the best materials often come from "people who are passionate about what they are doing and want to share it. I'm committed to the ideals of the Dead Poets Society—you know, the charismatic teacher being the vehicle to excite students." That principle, he adds, is why Wikipedia has become so much more popular than *Encyclopedia Britannica*.

Toward that end, he's built a studio on campus that films presentations from fellow scientists. The materials are then posted on a site called GEOSET (Global Education Outreach for Science Engineering and Technology). The process is idiosyncratic—"if I hear about a good presentation on a particular topic, I ask the person to come by," he explains—and runs on a tiny budget drawn mostly from university start-up funds. "I generally like to show people what I can do before I ask them for money," Kroto says. "It was the same for my research on C_{60}."

With 75 modules available, the bulk aimed at students from high school through graduate school, Kroto says it's time to start thinking of scaling up his digital library (geoset.group.shef.ac.uk). "I'd love to see this happening on hundreds of campuses," he says, ticking off collaborators in the United Kingdom, Portugal, Croatia, and Japan. "All it needs is a room with the right equipment and someone who's really committed to the task." **–J.D.M.**

heighten student interest in science, and make high-quality material readily available to parents, teachers, and students.

Lee Zia, NSDL's longtime program director, says that those statements, in hindsight, were "idealistic. The rhetoric at the time—greater connectivity would usher in this new era of educational achievement—was compelling." He insists that NSF never tried to hype NSDL. "We'd rather be in a position of underpromising and overdelivering," he explains.

NSDL was not NSF's first exposure to digital libraries. In 1994, it joined with other federal agencies to fund a team at Stanford University trying "to develop the enabling technologies for a single, integrated and universal digital library." A few years later, two graduate students on that project, Sergey Brin and Larry Page, used the search engine being created to found Google.

NSF officials weren't trying to replicate Google's commercial success when they launched NSDL. But as the Internet grew in importance, they began to ask how it could help teachers and students. There was already a lot of potentially useful content on the Web, some of it funded by other NSF programs and considered to be of high quality. But it was neither easy to find nor readily tailored for the classroom. As Zia puts it, "If you wanted to turn great piles of stuff into piles of great stuff, the first thing you needed was an infrastructure."
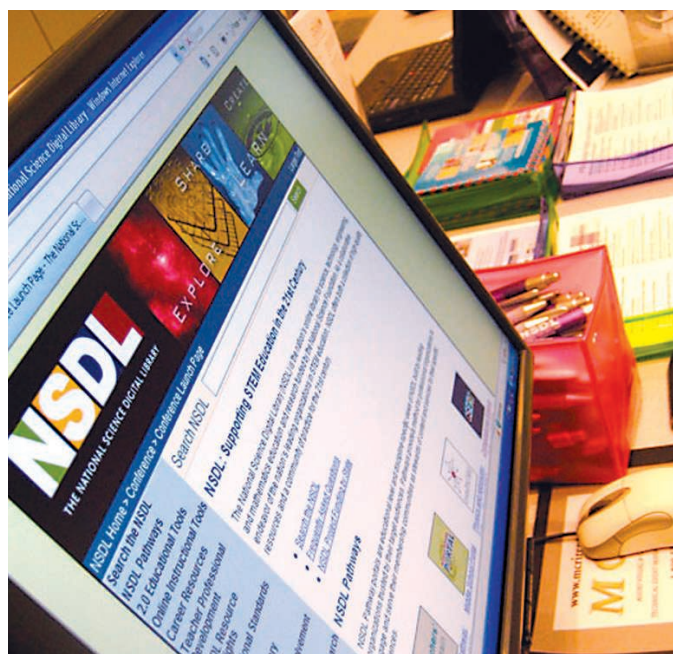
To provide that infrastructure, NSF funded "core integration" groups at the University Corporation for Atmospheric Research in Boulder, Colorado; Cornell University; and Columbia University to operate the main portal. They set out to develop technical standards, define the scope of the library, troubleshoot problems, and anticipate users' future

needs. The service component was a new wrinkle on NSF's traditional approach of supporting cutting-edge research. "It was an unusual activity for NSF," explains Zia. "NSDL was both a traditional program to fund research on an emerging technology [the Web] and an evolving entity that needed to be supported and sustained."

Once the administrative structure was in place, NSF put out a call for the community to compile collections that would link with NSDL. Over the years, NSF has funded 13 so-called Pathways serving both individual scientific disciplines and various user communities, including new ones this fall for the computing sciences and the quantitative social sciences.

One major Pathway activity is to post material that other NSF programs had funded over the years, much of it created by those same organizations managing individual Pathways. "NSF has invested in a lot of educational resources, and this is a way to archive everything that the societies had done, including things that may have gone out of print," says Yolanda George, deputy director of education and human resources at AAAS in Washington, D.C., which operates BEN (biosciednet.org). Each Pathway is also supposed to be the hub for an interactive community of users.

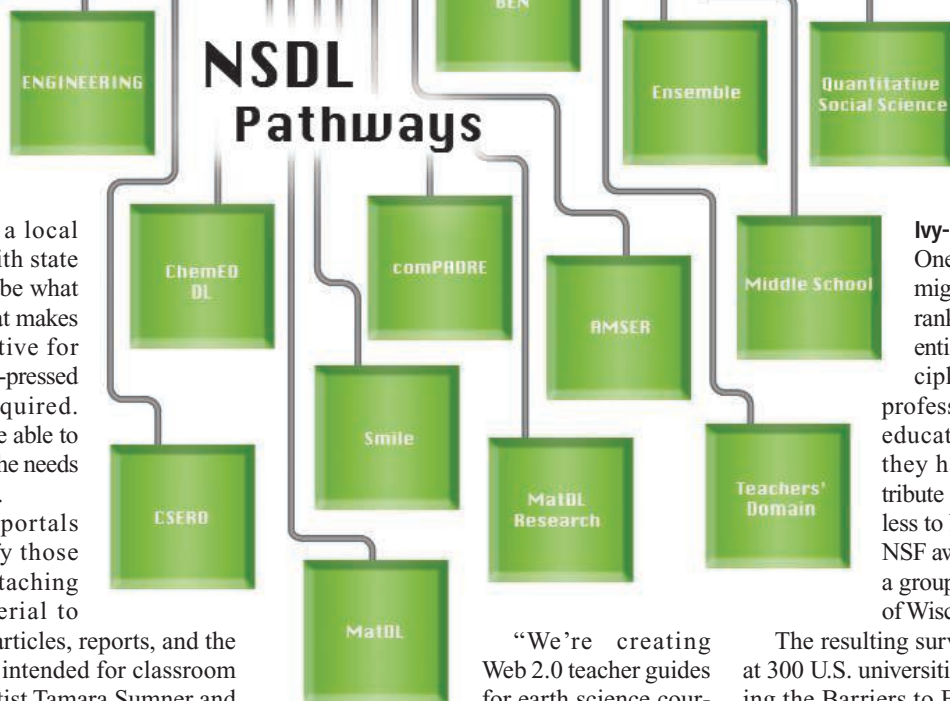Run by a consortium of 26 professional societies, BEN has put up 11,000 peer-reviewed resources—everything from scientific papers and reports to lectures and lab experiments—toward a goal of 25,000 by 2010. But to George, quality is more important than quantity. "Other people think that more is better," she says. "I don't agree. I'd rather have a nice-sized catalog of peer-reviewed material that promotes active learning than a vast amount of stuff that hasn't been vetted."

NSDL Pathways

ENGINEERING

BEN

Ensemble

Quantitative Social Science

ChemED DL

comPADRE

Middle School

AMSER

CSERD

Smile

MatDL Research

Teachers' Domain

MatDL

Low quality isn't the only reason teachers might avoid Web-based material. Most online resources aren't aligned with the existing curricula of a local school district or with state standards that describe what should be taught. That makes it much less attractive for teachers already hard-pressed to cover what's required. Teachers must also be able to tailor the material to the needs of individual students.

Many Pathway portals have tried to satisfy those requirements by attaching supplemental material to resources—journal articles, reports, and the like—not originally intended for classroom use. Cognitive scientist Tamara Sumner and her colleagues at the University of Colorado, Boulder, are tackling the issue head on. In 2007, she began working with secondary school earth science teachers in the Denver Public Schools to use NSDL resources to customize the district's curriculum in an interactive fashion. The curriculum was created by the American Geological Institute and is published by It's About Time, the Armonk, New York–based education division of Herff Jones that works mainly with NSF-funded curricula. Sumner, who has several NSDL-related research grants and is also co–principal investigator with Cornell on one of the two remaining infrastructure grants that NSDL supports, contributes both her expertise in teacher training and her knowledge of NSDL.

"We're creating Web 2.0 teacher guides for earth science courses," she explains about a pilot study now under way to give Denver teachers an interactive platform to develop individualized lesson plans. It allows them to integrate information from the district's own IT system, which teachers now use to maintain student records and track their performance on ongoing formative assessments as well as year-end standardized tests, with material tailored to address the needs of students across a range of abilities, from gifted and talented to English language learners.

Jim Short, then science coordinator for the Denver schools, says he was attracted by Sumner's previous work in organizing NSDL material to give teachers immediate access to exactly what they might need, when they need it. "I wasn't interested in more curriculum," says Short. "But imagine how useful it would be for a teacher to link the concepts from an activity to an embedded assessment, then ask, 'What key question would help me know if the student got the concept?' and then not have to search for the answer because the appropriate resources are already tagged."

A former biology teacher who now directs the Gottesman Center for Science Teaching and Learning at the American Museum of Natural History in New York City, Short believes that the guides should help even the most experienced teachers. "I don't think teachers have the time or expertise to put it all together themselves," he says.
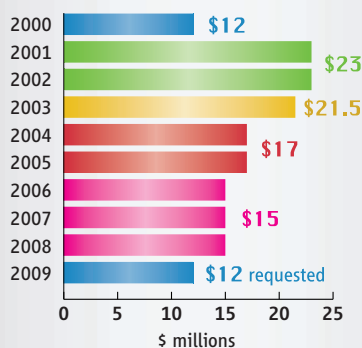
To teach a child. NSF has funded 13 Pathways projects to gather and disseminate material by discipline and sector. See below for URLs.

Ivy-covered indifference

One group that presumably might have such expertise is rank-and-file academic scientists. Despite their vast disciplinary knowledge and a professional responsibility to educate the next generation, they have been slow to contribute to digital libraries, much less to NSDL. To find out why, NSF awarded a grant in 2005 to a group based at the University of Wisconsin, Madison.

The resulting survey of faculty members at 300 U.S. universities (its title was "Lowering the Barriers to Faculty Participation in NSDL") doesn't provide a direct answer. But it adds to the previously meager pool of information on how academics use online

Links...

A Pathway to the Pathways
To access these NSDL portals, go to:

Biology: biosciednet.org
Chemistry: jchemed.chem.wisc.edu
Computational science: shodor.org/refdesk
Computing science: computingportal.org
Engineering: engineeringpathway.com/ep/
Materials science: matdl.org
Mathematics: mathdl.maa.org
Physics and astronomy: compadre. org
Social sciences: qssdl.org
Community colleges: amser.org
Informal science: howtosmile.org
Middle school: msteacher.org
Teachers: teachersdomain.org

resources. The survey found, among other things, that they are prone to do their own searches and value speed as highly as they do quality, and that the material they download is most likely to be used in lectures. An overwhelming number say they are self-taught.

"The biggest surprise to me is their reliance on Google," says Alan Wolf, a co-author of the study, which he says was one of the first to ask such questions. Their methods are likely crude, he says—"they tend to spend a great deal of

NSDL BUDGET

Year	$ millions
2000	$12
2001	$23
2002	
2003	$21.5
2004	$17
2005	
2006	$15
2007	
2008	
2009	$12 requested

$ millions

A digital rise and fall. The budget of NSF's National Science Digital Library has fallen from its early days.

A Vision in Search of Funding

Last summer, the U.S. government created an awkwardly named entity to fund research on how the Internet can improve U.S. education. But so far, the National Center for Research in Advanced Information and Digital Technologies exists only on paper.

Anecdotal evidence abounds of students getting excited about science through video games and other electronic educational resources. But the research to back up that premise is thin. Advocates of the new center persuaded Congress to take the first step as part of legislation reauthorizing U.S. policies toward higher education that became law last summer. But none of the $50 million that supporters are seeking in start-up funding has been appropriated.

Its backers have been deliberately vague about what type of research the nonprofit center would fund so that experts can set the agenda—and to attract as much support as possible. Michelle Lucey-Roper of the Federation of American Scientists (FAS) in Washington, D.C., which has led the campaign, sees it funding "precompetitive research on innovative learning tools serving all levels of society," from preschoolers to retirees, and in settings as different as the battlefield and the factory floor. The center would be an odd creature in the federal research zoo: Although housed within the Department of Education, it would nevertheless have an independent policymaking board and be free to solicit money from other agencies and from the private sector.

Supporters hope President-elect Barack Obama will ask Congress to fund the center in his 2010 budget submission. They note that his campaign promises to use technology to improve education and to double funding for education research point to his support for the concept. But FAS isn't waiting for the new Administration. It's already raised a bit of money to come up with an operating plan and management structure so that the center can hit the ground running if Congress ever funds it.

–J.D.M.

support of academic research: Applicants should address cutting-edge research questions, funding is for a finite period, and successful projects must figure out other ways to scale up or be sustained indefinitely. "A colleague of mine is fond of saying that there's only one thing that's certain about an NSF grant: It always ends," says Sumner, who is quick to add that she's very grateful for NSF's continued support of her research at the University of Colorado, Boulder.

Still, Sumner and others are disappointed that NSDL isn't better known. "Could NSF have done a better job of marketing NSDL? Absolutely, but NSF doesn't fund marketing efforts," she says. "They funded the research and the service components. There was never a product-development group with a marketing department, as would be the case for any commercial business."

In addition to a marketing department, companies also have an advantage over NSDL because their products are obvious. Identifying exactly what NSDL has to offer is much trickier. Although a contractor is laying the groundwork for outside experts to do a thorough program evaluation, Zia admits that "it's going to be much harder to figure out the impact of NSDL on a particular student or school." Given the privacy issues involved in trying to trace a user's Web behavior, he adds, "I don't even know if it could be done." **–JEFFREY MERVIS**

time looking for something that they assume exists"—and they often do it with a sense of urgency, "say, for a lecture the next day."

Wolf, a biologist who directs the New Media Center program at Wisconsin, doesn't know how elementary and secondary schoolteachers would answer a similar survey. But he guesses that "their use of Google as a search engine is likely to be similar." He also speculates that the quality of what's on the Web is less of an obstacle to faculty members than to K–12 teachers. "They are experts and probably feel capable of judging the accuracy and suitability of the material" for their students, he says.

An uncertain future

In fact, Zia expects expert knowledge to play a bigger role in NSDL as its progress tracks the evolution of the Web. Begun as an information commons, the Web then became a mechanism to foster social networking and interactivity. But NSF is already planning for Web 3.0.

"That's a return to editorialization," explains Zia, on leave this year as a policy fellow in the office of U.S. Senator Jay Rockefeller (D–WV). "It's something to help the user get the content in the right context. It adds an interpretative component that's now missing."

Whether NSDL will be part of that next iteration of the Web remains an open question, however. The program was always an odd fit at NSF. The agency's deep roots in the academic research community don't necessarily help it

nourish science teachers in thousands of local school districts. Those teachers need help solving problems that are often unfamiliar to academic researchers. "When we began 8 years ago," says Utah State's Recker, "we assumed that we could build a resource bank of high-quality interactive material and that change would follow. That was naïve. Once we started to go into the classrooms, we realized the complexity of the environment."

NSDL must also operate within the rules that have made NSF a model agency for federal

Pulling it together. An NSF-funded project is giving these Denver high school teachers a chance to customize their district's curriculum with online resources.