

Digital Libraries: A New Way of Doing Business in Science Education
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Today we face a changing landscape in education. For the first time, our country needs and expects learning opportunities that begin at birth and continue through one's lifetime. Education, and particularly college education, is no longer a once-in-a-life-time experience designed to imbue one with the knowledge and skills needed for a successful career. Instead, we now have a culture where learning goals change through life as an individual's interests shift and they adapt to a rapidly changing workplace. At the same time, and indeed driven by many of the same forces that are impacting the working world, we have new ways of teaching and learning enabled by new technologies. In this environment, we need to rethink the role of learner, teacher, department and the connections between academia and society.

One of the most exciting new developments in education is the advent of digital libraries. Digital libraries build on the full tradition of collections and services that libraries provide as community resources. A digital library provides collections of websites or URLs that can be accessed by users via the Internet. Advances in information technology make it possible to provide a very flexible discovery system or catalog that can be searched in a multiplicity of ways tailored to a specific user's goals. Digital libraries incorporate a variety of services to support the use of digital resources including on-line help, personalized collections, and document management. As a community center, digital libraries use discussion groups, e-bulletin boards, and other electronic communications to support community activities.

Digital libraries supporting math, science, engineering, and technology education are now under development. A variety of groups have already implemented sites that have one or more of the features of a complete library in a specific discipline (e.g. www.dlese.org, www.prsc-online.org, www.mathforum.org). Last year the National Science Foundation initiated a project to create an integrated, full-service digital library for education, the National Science, Mathematics, Engineering, and Technology Education Digital Library (NSDL; www.nsdl.nsf.org and www.smete.org), which is envisioned as providing seamless access to learning resources, services, and networks supporting teachers and learners at all levels and in all venues. The NSDL will also provide services supporting effective use of resources, and enable learners at all levels to work directly with scientific data to support inquiry-based instruction and an understanding of the process of science.

Digital libraries serving education create four major new opportunities that could have a profound impact on the educational enterprise:

1. Broad sharing of reusable learning resources. Digital libraries hold the promise of allowing faculty to quickly learn about and obtain curriculum materials, lab exercises, problem sets and other learning resources used by other faculty in teaching a particular topic. This capability means that faculty can share and borrow each other's teaching ideas with unprecedented ease. Creation of good digital resources is time consuming. In response, we can imagine a future where the digital library can enable a community-wide effort to collectively create, share, enhance, and adapt digital learning resources. Web-based communication networks can support this development by discussing resource effectiveness enabling continual improvement of materials. This model could introduce major efficiencies in the creation of teaching resources which have traditionally been done by individual faculty members in isolation.

2. Data aggregation and sharing for science and education Digital libraries and modern information technology make it possible to collect data from across a community and aggregate it into a single virtual collection. The power of this approach in allowing distributed observers to create an integrated data set has been demonstrated by the GLOBE Project that coordinates international environmental data collection. This capability applied to science education will allow educators across the community to integrate their learning assessments for a particular resource, a specific course, or a pedagogical approach. Similarly, aggregated virtual datasets will provide new opportunities for both scientists and students to explore scientific data, asking their own questions and seeking their own answers.

3. Specialized communication networks A digital library system for education makes it possible to create conversations among educators who share specific interests within a very large community. For example, it is now relatively simple for a community college physics professor to find colleagues who share similar teaching interests, or to find help for a faculty member interested in learning how a specific piece of lab equipment works from colleagues across the virtual community who have tested the equipment.

4. National and international coordinated community action The combination of communication networks and shared resources opens new possibilities for collective action. For example, we can share information on individual efforts aimed at increasing diversity in the physics community, develop a community wide discussion of the issues and results, and create an integrated plan creating synergies between efforts. Likewise, it is possible to poll the community on issues of science education to create a strong voice for political influence. While the possibility of coordinated community wide action in science education is not new, digital library technology greatly decreases the costs and time involved in organizing such an effort while increasing the speed and ease with which information can be shared.

Digital libraries have profound implications for the mission and operation of undergraduate physics departments. Undergraduate departments have always been at the nexus of relations among all interests of the educational spectrum: receiving students from K-12 systems; preparing teachers who instruct these students; providing content knowledge and skill development for majors and general scientific literacy through service courses; preparing the scientific workforce through professional training at the graduate level and continued professional development for working scientists; and engaging outreach to the community through a variety of media and institutions of informal education such as museums. Digital libraries have the capability of supporting these roles through emerging information services, data systems and communication networks.

In a digital world there are numerous new or expanded roles for departments. Access to high-quality and peer-reviewed instructional resources via digital libraries will help to create and support exciting and engaging learning environments across the curriculum. New organizational structures for content can create new linkages between topics in courses creating a coherent, integrated curriculum. New communication networks between students, instructors and content specialists provide new opportunities for personal growth for students and faculty alike.

Digital libraries also provide new opportunities for departments to share their work with the larger community and to break down barriers between school and work (or life). Resource sharing, supported by excellent topical discovery systems, will increasingly enable synergies that derive from connections to departments and colleagues

in sister disciplines, federal and state agencies, and industrial associates. Faculty and industry exchanges, as well as student internships, will be facilitated through exchange of information and methodologies in real and virtual settings. Effective transfer of cutting edge technology to the classroom will enable better preparation of future scientists for the workforce in the academy or industry. In-class exercises that emphasize true research, research-like, or service-learning activities to solve real-life problems will become increasingly practical using analytical, modeling, visualization, and simulation techniques. The good works of students and faculty, in the classroom or laboratory, can be proactively showcased to the world, including current or future student employers. A department's curriculum, resources, research projects and other programs can be held up to public scrutiny through e-dissemination—for recognition and awards for the department and individuals, and for accountability to our Science (via peer review), institutions, academic peers, and a public that deserves to know.

The digital age defines new roles for faculty as well. Given near-universal access to information, faculty will increasingly interact with students as mentors guiding inquiry and discovery. The rapid expansion of the knowledge base will lead faculty and students to work more commonly as co-discoverers in emerging fields of science, and faculty will encounter continuing and increasing need for professional renewal and development. In formal class activities, faculty will have to critically evaluate what is most important for students to learn and do, and they will have increasing need and opportunity to create, adopt, adapt, and repurpose instructional resources. To promote excellence in education, faculty will have to link content to best educational practices, and engage assessment of learning through the creation and use of appropriate metrics and tools. Faculty cannot be expected to be masters of all aspects of scholarship, and e-networks will become a standard resource to help faculty form and contribute to information networks, seek support, offer advice, and share resources.

Students supported by digital libraries also have new opportunities. They can develop self-defined learning goals and outcomes, according to personal interests and needs combining on-line and departmental resources. Personalized learning paths become possible based on the ability to navigate as deep into a topic as need and interest dictate, and laterally through cognate topics related by overarching concepts, applications, or at disciplinary interfaces. Multiple pathways to the same learning goal can be explored, according to different learning styles, personal experience, and local opportunities. Students will also have the ability to independently form extended communication networks with peers, mentors, and experts and will realize more opportunities to link content (i.e. coursework) with opportunities (e.g. REU, internships...)

The digital age presents many new opportunities for departments, faculty, students and broader communities. We'd like to invite you to explore and share our common scientific interests across traditional disciplinary boundaries, to learn from our experience in developing the Digital Library for Earth System Education (DLESE), and join the National SMETE Digital Library to develop digital library to support physics education for all.