

Virtual Laboratory Digital Library (VLDL)
A Review of Literature, Trends, and Granted Projects

The literature regarding virtual laboratories and their contributions to the advancement of all aspects of STEM education is vast. Carnevale discusses the interactive nature of virtual labs as essential to this Nintendo generation of undergraduates who crave more active learning. Mannix touts virtual labs for taking the tedium out of the number-crunching demanded of laboratory experiments requiring a re-computation of data as variables are changed. Many authors list the economy of scale of virtual labs, the ease of changing variables easily for student assignments, the safety aspect, the democratization of virtual labs to reach students who live in geographically-isolated or are underserved by poverty, the marketing of science to students outside the traditional 18-24 year old range, the self-contained nature of a virtual lab with handouts and texts included in the activities, and the sharing of resources in collaborative arrangements as being the most important motivations for developing virtual laboratories. Monitoring student progress quickly and leading institutions to a more significant online presence are other reasons detailed by the literature about virtual laboratories (Mannix, 2000) (Carnevale, 2003).

The significance of virtual libraries' impact on science education centers on the ability to forge enhanced collaborative relationships among students and professors of science. New areas of science are developing that cross-walk across disciplines to include components of several sciences. It is imperative that scientists of all disciplines have avenues for collaboration that meet in a multi-disciplinary space. As an example, the National Institutes

of Health has a new initiative titled “Digital Biology” that merges biomedical computation with medicine (Huang, 2004). Science is also becoming more data intensive, because of the shortened research and publishing cycle, and ways to compute, gather, disseminate, and publish results are being explored to facilitate those processes more efficiently and deliver to a global audience. Constructivist teaching is a much-studied pedagogy that is supported by STEM-content digital libraries (Luce & Giacomo, 2003). Student learning is enhanced by shared inquiry, discussions, common understanding, and goal achievement by building social venues into online activities to promote peer interaction and collaborative opportunities (Carlos Vera, Cobos, Sanchez-Naranjo, & Pinto, 2006). With a market economy influencing higher education, there is competition for students and a need to tailor services and products to the customers (Janes, 2005). Students with disabilities can be a more marketable aspect for virtual laboratories (Mannix, 2000). A digital library of virtual laboratories helps professionals and students manage information excess via a term coined by J.R. Borck as "context personalization" (Borck, 2001; Cohen et al., 2000). Efficiency is the major reason for consolidating data into a manageable and personalized digital library (Pickett & Hamre, 2002).

Trends

Reflected in projects reported and grants received are five major trends in the development of digital libraries: collaborative projects, user services improvements, pedagogical content/dissemination enhancements, construction of new digital libraries, and metadata standardization. Many of the projects are conducted by large institutions that have been involved in the DL1 and DL2 phases of digital library development in the United States but many others are medium to large universities, representing private and public institutions.

Often these projects are continued projects that have been in development over several years. Economy of scale and the sharing of resources play a substantial part in these collaborations. Users, accustomed to the advancements made in the commercial ventures of iGoogle and MyYahoo, have higher expectations for digital collections now. Personalization and efficiency drives several of the projects noted. Improving instruction on teaching pedagogy is another trend. Established digital collections are enhancing their collections with lesson plans, annotations to record-level entries, and enhanced collegial activities like chat features and discussion boards. New digital libraries are being constructed across the disciplines to fill needs as in earth science, for example. The need for developing common metadata schemas and mechanisms for gathering data about resources is the subject of many grants and projects. As more and more digital collections expand and establish, sharing resources is a topic of much discussion and research.

Collaboration

Through the funding of the Wallenberg Global Learning Network, Virtual Labs at Stanford has developed a collaborative effort with the Swedish Uppsala Universitat's MedFarmDoIt project and has developed outreach activities to local school districts in California (Huang, 2004). Kent State University is using a NSF grant of \$1,943,413 to continue work through 2007 to integrate the resources of the Materials Science Digital Library collection and the resources generated by other government-funded collaborations to include the National Institute of Standards and Teaching, Purdue University, MIT, and Iowa State University. Nanoscale Interdisciplinary Research Teams, Materials Research Science and Engineering Centers, and International Materials Institutes will be added to the collaborative activities. Several NSF-SMETE grants totaling \$307,690 are being completed in 2007 by Duke University, the Colorado School of

Mines, and Virginia Polytechnic Institute and State University to merge NEEDS and TeachEngineering digital libraries into one resource. Activities will be to align the resources of the libraries to state standards, grow the collection, and increase participation of content providers and users. They are also interested in enhancing quality control and establishing review protocols for the content and to provide a non-profit strategy for sustainability for the future. The American Association of Physics Teachers will finish a \$1,421,280 NSF grant in 2007 to continue work on the ComPADRE program. The ComPADRE Pathway will continue developing stewardship for physics and astronomy resources in the NSDL and providing leadership for physics and astronomy activities on the internet. This project has great application to other organizations who want to gather scattered resources that would not otherwise have a reliable web presence.

User Services Improvements

Observing the success of MyLibrary-like services at Cornell, The Library and Information Technology Association (LITA) is quoted as saying "worth keeping an eye on" in regards to the switch from library focus to user focus (Cohen et al., 2000). Virginia Polytechnic Institute and State University began a NSF grant project in 2006 for \$449,912 to construct a customizable webface for students and faculty to access the NSDL. This project will have implications for digital library designers to find the resources and services this grant revealed to be responsive to users' needs. In a NSF grant by the Exploratorium of San Francisco, user tags will be developed for the NSDL of vocabulary used by youth and content leaders to be mapped against existing metadata to make the digital library more useful to the underserved audience targeted. Utah State University will finish a grant project in 2008 from a \$694,548 NSF award to improve the discoverability of course materials placed in open repositories. They are enabling federated

searching across the sites, are developing a portal to those repositories, and are helping facilitate metadata harvesting of the NSDL. The results of their study will reach to all colleges and universities served by open courseware repositories. Columbia University is using \$75,000 to finish a NSF grant to link digital library resources with at least 1,000 pedagogical content knowledge (PCK) annotations. They are using the Digital Library for Earth System Education as their testbed. Building on previous work, the University of Colorado at Boulder is using a \$74,723 NSF grant to develop a concept browsing interface for K- users of the NSDL.org digital library. This will allow teachers to find resources that support learning goals and science standards. A combined NSG grant of \$641,124 was awarded to Carnegie-Mellon and the University of Wisconsin-Madison to collaborate in adding tables of contents of textbooks to locate resource sin the ChemEd DLib in an innovative interface to that digital library. Pedagogical matter, level in the curriculum, and interaction mode is being added to item records. This project will finish in 2009.

Pedagogical Content/Dissemination Enhancements

The Maine Mathematics and Science Alliance is using \$897,266 to build a PRISMS digital collection to identify and describe web-based phenomena and representations and better ways to teach using them. Annotations will be written to enhance the usage of the K-12 science curriculum materials they will choose to align with state standards in STEM areas. This grant will be reported to NSF in 2007. A 2005 NSF grant of \$356,400 to the University of Wisconsin-Madison will use focus groups to ascertain why higher education faculty is not using the National Science Digital Library as expected. Data gathered will serve as a baseline for future developments of NSDL and related projects. Usage concerns are the focus of another NSF grant

for \$604,331 by the University of California-Riverside. The Analytical Sciences Digital Library is the platform to reorganize the resources using hierarchies, incorporating problem-solving and service learning methodologies, and to find ways to automatically harvest the metadata to make staff more efficient. TERC Inc. received a NSF grant of 684,884 to create and conduct 600 teacher workshops in earth science based on activities written for the Earth Exploration Toolbook. The workshops are unique in that participants will stay in their own geographical area and access the workshops as a teleconference with great effort going to recruit teachers of the underprivileged. The Exploratorium of San Francisco is using \$649,999 of a SMETE program grant to partner with a statewide after-school leader-training network to make use of new resources and activities found in the Exploratorium digital library and the NSDL as a basis for professional development institutes. Utah State University will finish a NSF grant in 2009 to use \$491,587 to teach middle to high-school and pre-service teachers how to use the resources found in the NSDL. Improvements in STEM education is addressed in designed learning activities for teachers in New York and Utah, urban and rural school districts. A closely-related project is one from Drexel University from a NSF grant of \$650,000 to be completed in 2008 to design a hybrid workshop model and support math teachers in integrating the resources of the NSDL into classroom work. Using MathForum as the test library, three identified groups of over 900 teachers will strengthen their mathematical content knowledge, pedagogy, and use of technology to support student learning in the classroom.

New DL Construction

Through a 2005 grant from the NSF's SMETE program for \$375,000, The American Psychological Association is constructing an Online Psychology Library to include rare multimedia stimulus materials. It will include experiments and demonstrations that are highly

interactive, a cumulative data archive for student study, and data extraction and analysis tools for a wide array of users. There are many more virtual libraries and virtual laboratories yet to read about.

Metadata Standardization

The Ohio State University Research Foundation is working on a continuing grant for \$847,791 in 2005 to join resources from the NSTA and the NSDL collections. A focus of this grant is to make uniform the metadata for all resources in both collections by selecting, describing, and cataloging digital resources. Another NSF-SMETE grant focuses on deploying a metadata registry service to complement the NSDL Central Metadata Repository. The University of Washington is using \$191,145 to share schema and schemes to improve services to users, using machine mapping of relationships among terms and concepts and to encourage the growth of registries and distributed registry networks.

Virtual Laboratory Examples

The investigation of virtual labs already in operation was necessary before writing a proposal for creating a digital library. After some reading and observing, a wide range of virtual labs was noted. There are commercially-prepared labs, labs that are little more than datasheets and handouts, labs that require equipment and materials from the home, and standalone virtual labs. Listed below are some virtual labs that were investigated and some annotations about their unique offerings.

- Virtual Engineering/Science Laboratory course at Johns Hopkins University that is Java and fully interactive for beginning science and engineering students covering concepts from logic circuits to probability distributions.
- 2002 Sci-Tech Web Award was given to Virtual Chemistry at University of Oxford that

has a section on Virtual Experiments including simple inorganic solids and interactive organic mechanism.

- Virtual Laboratory for Earthquake Engineering at University of Illinois at Urbana-Champaign has virtual experiments for testing structures and the parameters of earthquake properties.
- Iowa State University professor Thomas Greenbowe has beginning chemistry classes using 70 exercises and animations in his VL. The lab illustrates concepts like Boyle's law and molecular interactions such as the formation of hydrogen bonds.
- Interactive Multimedia Intelligent Tutoring System at Temple University's College of Engineering assists undergrads with their first circuits courses. It uses *Macromedia Authorware* to build a virtual office that has access to a virtual lab where students get assignments that entail analyzing designs created by the senior engineers or designing simple systems. The system has an automatic "expert" system that monitors progress, offers tutorials for skills not yet mastered (Butz, 2006).
- National Library of Medicine sponsors the Visible Human Anatomy project applications for usage in other written lab experiments/observations (Harden, 2003).
- Virtual Labs Project at SUMMIT (Stanford University Medical Media and Information Technology) has an intense range of interactive simulations about chemical, mechanical functions of the human body (Huang, 2004).
- Carnegie Mellon University pitches virtual chemistry lab to beginning undergrads with 20 investigations of probe topics. The applets are translated into four languages (Leslie, 2003).
- NetFrog Dissection from the University of Virginia has laboratory directions and illustrations and practice questions. It has been around for some time but is not interactive (Hamza, Alhalabi, Hsu, Larrondo-Petrie, & Marcovitz, 2002).
- Interactive environmental virtual field laboratory at Florida Agricultural Experiment Station is a virtual field trip to study water tables and soil composition (Ramasundaram, Grunwald, Mangeot, Comerford, & Bliss, 2005).
- McGraw-Hill's BioLabs is a commercially-sponsored self-contained site with experiments with accompanying manuals to discover genetic permutations, cell division,

and transpiration among other topics.

- Another commercial virtual lab is Biology Labs Online sponsored by grants from the U.S. National Science Foundation and the California State University.
- Dr. Biology's Pocket Seed Experiment is designed and offered by Arizona State University and includes data cards, plant growth and magnification of seed activity. They also sponsor a Virtual Aviary.

Observations Regarding User Features and Technology

The demand for user services in the face of features now available through Web 2.0 technology is palpable to any digital library designer. "Personalization is the key to successful management implementation" and so it is in a digital library. The designer must provide the search, navigation, analytical, and communication tools necessary for members of the community to do their work in a collaborative manner advises Pickett in his article on portals in higher education (Pickett & Hamre, 2002). Like Amazon recommending book titles to frequent user based on purchases and pages visited, a personalized web environment with "push" recommendations to users of digital libraries is desirable (Luce & Giacomo, 2003). Bookmarklet technology to stay in the portal for easy access to data is different from just bookmarked links. This is an application that actually draws data into the portal from an application found in an organization's LAN or from a website that supplies information that changes often.

Organizing an interface to serve as a portal adds more value than just being a collection of links. Vertical enterprise portal (VEP) is a customizable space that is unique to the user in an organization. A science professor could manage assignments for his students using his portal space. It would be a customizable, personalized adaptive desktop with collaborative tools to work with others, asynchronously or in real-time (Strauss).

The technology to bring user services to a digital library takes advantage of web and application servers, and database and browser software and helper applications. We are used to seeing enhancements to library OPACS such as MyLibrary and MyUpdates that allow the user to hold information in folder hierarchies and have new resources pushed to the personal library space of the user. RSS feeds could be employed to share news of recent additions to the digital library or to announce new procedures and other pertinent information to the user base. Shared space for distributing documents to students or to other science colleagues is a useful feature as well (Cohen et al., 2000; Luce & Giacomo, 2003). An instant messaging service within the portal would be a feature to enhance the communication among science educators as would a chat feature. Annotation features would be helpful at the item level. The annotations would have to be monitored but would provide valuable information about an experiment to alert the next user about a glitch, an interesting handout to accompany the lesson, or ways to adapt the experiment to account for specific variables not included in the original.

Security and backup plans for the digital library must be outlined and assurance that the digital library is always available is crucial in this globally accessed resource. Authenticating users to the digital library is a concern. Cornell uses Kerberos Authentication but institutions housing a digital library often have their own systems for this. A user profile is useful to glean what students' expectations are and to provide starter information for online discussions among users. There must be a FAQ section, online help, and access to technical support at the site. A link resolver is important to have for the digital library (Luce & Giacomo, 2003).

The quality of the interface is important and interactivity of the virtual lab is key as is realism (Bencomo, 2004; Mannix, 2000). Chu found that over 90% of students in a study on flexible learning reported that content should be more interactive (Chu & Leung, 2003). In terms of software, there should be no client software to download, relying instead on “generic” software like HTML and Java (Monge-Najera, Rossi, & Mendez-Estrada, 2001).

Metadata should, if at all possible, be harvested automatically and that requires a collection creator like RSLP (Research Support Libraries Programme) used at the University of North Carolina (Geisler, Giersch, McArthur, & McClelland, 2003). The NSDL uses Dublin Core for the DL metadata repository and aids in making available any native metadata available by collections or projects (National Science Digital Library, 2007). To enhance the sharing of data there should be a unique permanent identifier for each source and a date to aid in automatic capture (Luce & Giacomo, 2003). OAI harvesting (Open Archives Initiative Protocol) is being used as the primary method of bringing metadata into the metadata repository at the NSDL. A federated search to acquire resource description requires cooperation from the member digital libraries. There are two types of these: cooperative and not so. STARTS is a cooperative protocol that copies an accurate resource description to the directory service upon request from a cooperative digital library in a P2P (peer to peer) network and Sample-Resample is a resource selection algorithm that is accurate and has less communication costs to harvest information from an uncooperative digital library in a P2P network (Lu & Callan, 2004) .

It would seem that a new digital library must be beyond a listing of links. A digital library for virtual laboratories must itself serve as a virtual lab “office” to enter and find annotations,

collaboration space, and search tools to fashion a workspace that is self-contained. This portal, using bookmarklets, could pull in data that is necessary for the day's work and display news of current science events and resources. The digital library would manage the resource location of all items in a metadata process so aid in sharing and to be accurate in the search process. The digital library of virtual laboratories must be interactive, personalized, and fresh each time the user enters.

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