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Chapter · November 2020

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A.Elangovan
Head Librarian ,Institute of Management Technology, Dubai International Academic City Dubai-UAE, email : elangovan2007@gmail.com
Dr.Aravind .S
Librarian and Head, Central Library &Department of Library and Information Science, G.T.N. Arts College (Autonomous),Dindigul, India email: aragtn2601@yahoo.com

1. INTRODUCTION

In a library, be it digital or analog, the essential transaction is the same: a user interacts with content. But richer interaction is possible within the digital environment, not only as more content is put within reach of the user, but also as more tools and services are put directly in the hands of the user. These include the abilities to search, refer, validate, integrate, create, customize, publish, share, notify, and collaborate, to name but a few. Students, faculty, and those are pursuing continuing education will "connect to learn"; but they will also "learn to connect", as they leverage their participation with other users of the library and its resources.

By networking users and content with tools, the digital library enables three chains of support. First, users supported by profiles are able to form learning communities. These can be communities of one or they may be communities of thousands; they may be short-lived communities born of immediate needs, or they may grow into persistent communities. However, an important concern to acknowledge is the potential loss of privacy, which must be balanced against the potential gain in personalization of a user's experience. A second chain of support closely related to the first is that content supported by metadata enables the formation of customizable collections of educational objects and learning materials. These collections may target an individual or they may target a community; and they may learn and adapt to the behavior of their users. Finally, tools supported by common protocols or standards enable the development of varied application services that enhance the value of the library's content for the learner.

The following long-range objectives for DLEs

- Lifelong learning. Enrich
- Learning anytime anywhere.

- Distance learning demonstration programme.
- Government as “model user” of technology-based training.

For these objectives, a number of intermediate goals are formulated, such as:

- Improve the students learning skills
- Enrich the digital learning environment among the students and other user community to improve their learning capacity
- Increase the quantity, quality, and comprehensiveness of Internet-based scienceeducational resources.
- Make these resources easy to discover and retrieve for students, parents, and teachers.
- Ensure that these resources are available over time.

Studies show that the Internet has the potential to transform the highest level of education, but only a fraction of that potential is now being realized. Some of this gap lies in the maturation process that is part of any transition, but a larger part is the result of fragmentation. Resources of great value are not being used because of students and faculty may not aware about the resources, or they didn’t know to access the resources.

While great efforts have been placed on creating materials, less attention has been given to organizing and maintainingthe resources in the long term, helping the people to find the resources and provide adequate training to the users to easy accessing of the online resources. For example, a faculty member who is planning a course has only the most rudimentary tools to discover what materials are available or whether they have proved effective in other courses. A student who is researching a topic is forced to choose between general-purpose Web search services and commercial databases designed for scientific and technical research. Neither faculty nor students can safely rely on resources that might be withdrawn without notice, or change subtly overnight.

A DLE is envisaged as a comprehensive library of the digital resources and services that are available for education in science, mathematics, engineering, technology, and other disciplines. The key word here is “comprehensive”. Faculty are very specific in wanting a

single place where they and their students can discover, use, and possibly contribute a wide range of materials.

A DLE is considered to be a federation of library services and collections that function together to create a digital learning community. Organizationally, a DLE will consist of a small central operation with a wide range of partners. Some of the services and collections are already well organized; for these, the DLE will act as a gateway. Others exist but are poorly organized; for these, the DLE will stimulate the creation of specific services. Some materials are fragmented, unorganized, or hard to find; in these cases the DLEs will build library services and may even manage specific collections. Across all these areas, the DLEs will provide tools to help faculty and students find and use materials, with services to assist them in evaluating quality and appropriateness.

DLEs will take a broad view of science and technology, and scientific education. The primary audience is faculty and students, but there is no hard distinction between the needs of high school students, undergraduates, and graduate students, nor between students in formal programmes, independent learners, and the general public. DLEs should have a variety of financial models for access to the materials; some content will be free of charge while other materials will be available on a fee basis.

The range includes curricula and courseware materials, lectures, lesson plans, computer programmes, models and simulations, intelligent tutoring systems, access to remote scientific instruments, project-based learning, tools, the results of educational research, scientific research reported both formally in journals and informally in web sites, raw data for student activities, and multimedia (image, audio, or video) banks. DLEs should provide services for authors and instructors, such as annotation, evaluation, and peer review of donated materials. For students and faculty, they will offer the capability to search for desired information by subject area, to have access to scientific data sets, to interact with peers, and to provide archiving, location-independent naming, recommender systems, selective dissemination of information, and copyright management. Faculty, students, and other clients, such as independent learners, will be able to participate in forums. Interdisciplinary activities, lifelong learning, and the process of education will all benefit. In

this way, the DLE will be much more than the sum of its parts, and will promote change and innovation in scientific and technical education at all levels.

The following are guiding principles that DLEs should follow:

1. Be driven by educational and scientific needs.
2. Facilitate educational innovations.
3. Be stable, reliable, and permanent.
4. Be accessible to all (though not all materials will be free).
5. Build on, and leverage, past and current work in courseware libraries, digital library research, and successful commercial sites.
6. Be adaptable to new technologies.
7. Support the decentralized creation of services.
8. Provide tools and organizational background for the integration of onlineresources.
9. DLE should be integrated with Learning Management Systems (LMS)
10. Online resources to be integrated with LMS
11. Mobile application will be highly essential to implement the DLE

DLEs are intended to encourage the dissemination of research in educational methods. They will also facilitate the involvement of industry and government laboratories in the educational process. Whereas some universities benefit from guest speakers from industry or government in the classroom, not all schools are able to arrange such visits. The digital library, enabled by new information technologies, would provide a forum for real time video or voice communication to a wider range of learners. These virtual lectures and discussions could be captured and then added to the library for later access.

DLEs will also facilitate cross-institutional sharing of educational resources, including all types of courseware, as well as materials for distance and self-learning. The ultimate goal is the development of a community of science and technology educators who use the library for cross-disciplinary and cross-institutional collaboration. Access and discussions with authors and prior users would be possible, along with an archive of past reviews and discussion of materials in the DLE. The collections could be annotated and linked to these discussions and reviews.

The digital library also opens the opportunity for students at different institutions to work on joint projects or experiments, perhaps sharing and adding to the same data set and its analysis. This would also promote physical resource sharing, as students and instructors may have varying access to high-end instrumentation, computational capabilities, data collections, and technology.

The following rationale for DLEs in science and math has been expressed

1. Student performance in math and science is poor and needs to be improved.
2. Today's Internet lacks the cataloguing, organization, archiving, collections management, etc., of a library.
3. The effort to connect every classroom to the Internet will be of limited value without high-quality content.
4. A digital library can be a resource for the entire population (marginal cost of dissemination is almost zero).

One of the methods of determining the success of digital libraries in improvement of student learning is to examine whether they are helping to achieve pedagogical objectives. Development of scientific thinking in students might be one of the criteria. Examples of skills that are to be developed in students by educators are asking questions, acquiring information, organizing information, analyzing information, and answering questions in certain scientific disciplines.

Accessibility is an important property of DLEs that requires a two-part strategy. The first is that the library should be realistic in its technical expectations. Since a range of factors, including network bandwidth, availability of computers, and costs, can limit accessibility, the library must be designed to accommodate a wide range of users and be realistic about the technology that they use. However, not all DLE services need be limited to the lowest common denominator of the current capabilities of computers, networks, students, and faculty. Technology is improving rapidly, and the library must grow with it.

The second part of the strategy is that the DLE should work vigorously with concerned individuals and organizations, including federal and local agencies, to ensure that

all students and faculty have good Internet access. Modern scientific and technical education requires that all faculty and students have computers and telecommunications, with the training to use them effectively.

Sustainability is another important property of DLEs. There are strong arguments for the national DLE to be considered a "national treasure" and supported as a public good; indeed the frequent calls for open, free access to content are rooted in this view. An attractive scenario for the long-term management of the digital library is to place responsibility in the hands of a non-profit organization.

This vision of DLEs still begs the question of how creators will be compensated for their efforts. For contributions of "fine-grained" content (e.g. short Applet tutorials or simulators) the digital library can offer recognition from peers, which would be suitable and important "compensation". Digital rights management technologies also hold promise for identifying usage of, and then appropriately providing compensation for, content. This would allow the creators and purveyors of content to differentially price and/or repackage portions of "coarse-grained" material that has been disaggregated (some publishers have begun to offer custom runs of selected textbook chapters to professors). It has been observed that reconceptualizing information as a service rather than a good offers the opportunity for new revenue streams that can be directed back towards content creators. This view suggests interesting possibilities for the development of new services for users that could be available, for example, individually or through affiliation with existing organizations, such as professional societies. More generally, these considerations may lead to rethinking of reward systems, such as promotion and tenure, to reflect the importance of developing, sharing, and using educational resources in DLs.

The role of digital libraries in the learning environment will be clarified further. First, models of learning environments will be characterized.

2. TASKS OF DIGITAL LIBRARIES IN THE LEARNING ENVIRONMENTS

Within the context of changes in society, technology, and education in recent years, there have been two keydevelopments relating to e-learning infrastructure in UK universities and colleges:

- The adoption of virtual learning environments and managed learning environments.

- The implementation of digital and hybrid libraries.

VLEs are tools which support e-learning through the provision and integration of Web-based materials, includinglearning materials, links to other resources, online communication tools (such as electronic bulletin boards), andassessment tools. When such VLEs are integrated with other information systems and processes of the institution, e.g.student records, the resultant system is generally referred to as aManaged Learning Environments (MLE).

For VLEs, truly digital libraries are required with all resources and services available online. Some of the candidate tasksthat DLEs could support include:

1. Highly directed uses, such as lab exercises to reinforce a specific disciplinary concept.
2. Instructional modules that introduce concepts in an incremental manner and can be customized and extended byfaculty for use in lectures.
3. Free form exploration conducted by students preparing term papers or faculty putting together a lecture that mightinclude personal manipulation of data sets, information visualization, and the integration of new information ordata sets to augment existing content.
4. Collaborative applications that might be used by students doing team projects or faculty and teaching assistants whoare team teaching.
5. Discipline- or domain-specific methods of building knowledge that support specific information seeking and useprocesses.

The key characteristic of learners with regard to the linkage of VLEs with digital libraries is their diversity. More andmore learners are learning from home, from their workplace, part-time, or from a geographical distance to their course.They are coming from all age groups, and are learning throughout their lives. They are coming to the universityexpecting more, based on their experiences with the Internet and other information and communication technologies.

There is no longer a typical "higher education" learner. Where library and information resource support to teachingwas once comfortably housed in a library building, that support must now be provided to all students regardless of themedium or location of their learning.

3. GENERAL CRITERIA FOR DIGITAL LIBRARY QUALITY WITHIN THE LEARNING ENVIRONMENT

- **Quality of the resources to be discovered in the library:** There is a great deal of discussion and divergence — some librariesfocus on quantity as in the public library model; some focus on quality, as in specialized collections that might be foundin a public library.

- **Seamless access:** This includes seamless integration between the learning environment and the library or informationresources at any point in the VLE and within one user's portal across different courses, departments, or eveninstitutions. The most important aspect of this was the single sign-on; one authentication procedure, regardless ofwhether the user is accessing the VLE from on- or off-campus.Warning notes that were sounded included potential problems with seamless cross-searching of different databases,indexes, and other information resources.3 Lack of interoperability of search vocabularies, and a lack of awareness of andstrategies to deal with this in course design, could lead to confusing, ineffective resource discovery experiences for learners.

- **All library functions online:** Concerns about this include the potential diminishment of two important educational functionsof traditional libraries: serendipitous browsing (finding the book you need right next to the one you were actuallysearching for); and their social function as a place to meet fellow students and discuss sources of information, etc.

- **Individualization for the learner:** This concept includes such ideas as the student portal, which could cross institutions and be available throughout a learner's life; the Amazon.com idea of tailoring resources and notifying the user about relevant resources; the ability to save and share searches; the ability to take and embed notes

with information resources, and to share resources; and settings for "level", such as undergraduate, third-year, etc., with options to adjust upwards if the user wishes.

- **Flexibility for the teacher:** Teachers would like to be able to adapt or update courses easily, including the information resources embedded in or linked to them, from anywhere. Flexibility in terms of being able to design the course according to their own pedagogical approach, rather than having it dictated by the system, was also seen as extremely important, and vital for bringing academics onboard with e-learning. Finally, the system should have the capability to feed back data to the teacher about what information resources and services are being used.

- **Universal accessibility:** Universal accessibility includes accessibility for users with differing physical abilities, adaptability to differing learning styles; availability on- and off-campus (an issue with regard to certain subscription library materials), equitable access for distance learners abroad (usually the biggest problems are access to hard copy resources and time zone problems with communications), equitable access for the economically disadvantaged (those who have to wait in line at a computer centre versus those with a PC or laptop oftheir own), and usability on any platform or hardware.

4. CONCLUSION

Digital libraries have become a core ingredient, a collective memory of the educational environments of today and of the future. Hybrid libraries have already become widely used components of many universities around the world. In several countries a national digital library for education in science, engineering, and technology is being developed as an important ingredient of the national educational infrastructure. While the development of a DLE is a continuous process of collecting, classifying, conceptualizing, and using information, the process is paralleled by rapid technological advancements.

The development of national DLEs requires the involvement of various groups in society. Besides educators and learners, the community includes members of professional societies, information providers, researchers, and representatives of industries. Interrelationship of the interests of the community members should be addressed, in order to develop a reasonable strategy leading to DLE sustainable development and gradual

evolution. This process leads to formation of a wide community around the DLE, providing for development, governance, collecting of information, and use in education. DLEs should provide various services, such as cataloguing, archiving, selective dissemination of courseware and other instructional materials developed internationally, annotation, evaluation, cross-lingual search and retrieval, personalization, recommendation, instructor support, and copyright management. DLE development programmes in the rest of the world need additional serious analysis. Even collecting information about the state-of the- art in different countries is difficult, because of the insufficient level of information available and the diversity of the presentation languages. Preserving the national language as well as a cultural and historical identity in the education and globalization of DLEs, Digital libraries are becoming a core ingredient, a collective memory, of the educational environments (global,national, university or domain-oriented) of today and of the future. The digital content of DLEs remains dependent on the language (or language groups) used by the educational community in each country, as well as the culture and national traditions in education.

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