Content + Connectivity = Community:
Digital Resources for a Learning Community

Gary Marchionini, Victor Nolet, *Hunter Williams, Wei Ding, Josephus Beale Jr., Anne Rose, Allison Gordon, Ernestine Enomoto, and Lynn Harbinson

Digital Library Research Group and Human-Computer Interaction Laboratory
University of Maryland, College Park, MD 20742

*Discovery Communications Inc.

{march, vnolet, hunter, weid, melc, arose, agordon, ernestine, lynnharb}@learn.umd.edu

January 10, 1997

Abstract

Digital libraries offer new opportunities to provide access to diverse resources beyond those held in school buildings and to allow teachers and learners to reach beyond classroom walls to other people to build distributed learning communities. Creating learning communities requires that teachers change their behaviors and the Baltimore Learning Community Project described here is based on the premise that access to resources should be tied to the assessment outcomes that increasingly drive curricula and classroom activity. Based on examination of curriculum guides and discussions with project teachers, an interface for the BLC digital library was prototyped. Three components (explore, construct, and present) of this user interface that allows teachers to find text, video, images, web sites, and instructional modules and create their own modules are described. Although the technological challenges of building learning communities are significant, the greater challenges are mainly social and political.

Introduction

A variety of self-contained digital resources ranging from drill and practice programs to shared MUDs and MOOs have found their way into classrooms at all levels. Integrated, digital libraries offer new opportunities to provide access to diverse, primary resources beyond those held in school buildings and to allow teachers and learners to reach beyond classroom walls to other people to build distributed learning communities. This paper describes the results of the first year of development of a learning community known as the Baltimore Learning Community (BLC) that links middle school teachers and learners through a shared multimedia corpus of materials that support science and social studies. Part of a five year project, we give an overview of key elements of the BLC from a digital library perspective and focus on an interface that provides cascading levels of user access.

Digital libraries have critical roles to play in the evolution of learning and teaching that leverage the capabilities of electronic information technologies. In addition to the usual potentials of hypermedia and multimedia for teaching and learning (e.g., broad, comprehensive access to materials; individualization; and multiple media of representation), we have argued that digital libraries will lead to increased integration in both spaces and functions of learning, i.e., integration of workplace, home, and school; and integration of work, informal learning, and formal learning (Marchionini & Maurer, 1995). Furthermore, we believe that bringing people and high-quality, well-organized digital resources together though telecommunication channels will enable new communities of practice devoted to learning and teaching (e.g., Pea, 1996). This belief was the basis for the BLC proposal to the US Department of Education Technology Challenge Grant Program (http://www.learn.umd.edu/papers and proposal/proposal.html) which was funded in September of 1995. The educational philosophies that underlie this project are constructivist learning theory (e.g., Kafai & Resnick, 1996) and outcome-oriented teaching practice (Nolet, Marchionini, & Enomoto, in review).

The Baltimore Learning Community (BLC)

The Baltimore Learning Community is a collaborative project of the University of Maryland at College Park (UMCP), Johns Hopkins University (JHU), and the Baltimore City Public Schools, funded as one of the US Department of Education Technology Challenge Grants. The goal of this five-year project is to create a learning community through use of high quality digital science and social studies resources and high-speed networking. The project has two major components that both target technology "have not" schools that serve high numbers of students who are academically at risk. One component of the project, lead by a team of researchers from JHU, employs interactive video conferencing and focuses on development of school-community links to facilitate effective school to work transitions. The other component of the project is lead by a team of researchers from the University of Maryland at College Park and focuses on development of effective solutions for integrating high quality digital video and other resources into middle school science and social studies classrooms and linking instruction that uses these resources to rigorous curriculum guidelines measured by a statewide performance assessment. This paper focuses on the UMCP component.

One goal of the Education Challenge Grants program is to demonstrate how school- university-business consortia can operate to improve educational outcomes through enhanced technology. Thus, our focus is on implementing and testing an approach to resources on demand that integrates techniques from varied research and development projects and on gaining experience with logistical and human-resource issues to inform other projects rather than conducting basic research on learning principles or digital libraries. In addition to the school and university partners, the BLC also involves a consortium of public organizations and private businesses that have made a major investment in the project. Discovery Communications Inc. participated actively in the development of the original project proposal and is providing up to 100 hours of digitized video programming from the Discovery Channel and The Learning Channel as well as ongoing technical and conceptual assistance. Discovery aims to learn through this project how its large collection of high-quality video resources may be repurposed in digital forms. Apple Computer Inc. has donated 40 computers for the project. The US National Archives and the Space Telescope Institute have provided significant content resources in both digital and non-digital formats.

Although the focus here is mainly on the technological aspects of the project, a fundamental challenge in community building is the logistics of human collaboration. The project brings together 15 teachers (six science, six social studies, three curriculum coordinators), principals and other school system administrators, more than a dozen UMCP faculty and graduate students, and industry and government partners. Only one university staffer is full time on the project, thus almost everyone associated with the project has a full time jib beyond the project and teachers are especially constrained by their teaching responsibilities through the daytime hours. Thus, face-to-face meetings of the whole group are extremely difficult to coordinate. Email and a BLC listserv play crucial roles in facilitating communication and thus fostering community building, but in the early stages of the project the faculty and graduate student visits to schools serve as the glue of the community.

Monitoring the roles electronic media play in evolving the community is an important aspect of the project evaluation.

At the time of writing, the BLC project had completed one full year of work, during which time the first phase of implementation was initiated. This phase includes acquiring and cataloging approximately 1500 digital objects; prototyping a WWW-based BLC gateway interface, resource exploration component and module construction component; conducting teacher training workshops and a summer institute; installing 48 computers with basic Internet connectivity in 12 classrooms; creating a set of instructional modules based on the first objects added; collecting baseline evaluation and research data; and providing basic project server and communication services to all participants.

Collection Development Policy and Procedures

The objects added to the BLC collection are determined by several factors. First, since it is our intention to build community, we have taken a user-centered perspective by involving teachers in the selection process. Interviews with teachers and regular written solicitations for specific materials are conducted. Although content acquisition mainly aims at using Discovery, Archives, and Space Telescope materials, we add WWW resources as well. Several hundred images from the US Archives were acquired and digitized during the summer of 1996 based on teacher requests. Discovery Channel met with the BLC teachers in early Spring 1996 to determine which topics would be of greatest interest to the community. As a result, Discovery produced five hours of original science and social studies programming based on existing footage for use in the trial: "Aquatic Habitats," "The Space Shuttle," "Wonders of Weather," "How the West Was Lost," and "The Revolutionary War." These five programs aired on Discovery Channel's educational service Assignment Discovery in Fall 1996 and now make up the first installment of Discovery's contribution to the digital library. Most recently, Discovery and Learning Channel programming for 1997 was sent to teachers and they were requested to identify those programs that should be considered for digitization (note that Discovery itself must go through a lengthy intellectual property rights process with producers of its video before providing video programs or segments to the project).

Secondly, the middle school social studies and science curricula for the Baltimore City Public Schools was used to guide acquisition. In addition to topics, curricula are shaped by school district and state instructional outcome standards. The Maryland State Performance Assessment Program defines outcome levels for topics. Our interviews with teachers demonstrated that although they select and organize instructional materials by topic (e.g., rivers), they must write and organize their lesson plans by MSPAP outcome. Thus, we decided to use topic and outcome as two organizing principles for collection development and access.

Five data types comprise the collection: text, images, video, WWW sites, and instructional modules contributed by teachers. Selection, acquisition, and management are described for each data type. With the exception of Discovery materials, all objects are in the public domain. In addition to teachers, UMCP faculty and graduate students in science and social studies education, and in information science are involved in content selection. At present, a simple indexing scheme is used to create a record for each object. This indexing is done by graduate students with school library media emphases in conjunction with graduate students with educational content emphases. For each object, 17 fields are defined, including two main topics and subtopics and two outcome categories each for both science and social studies. We have begun investigating more sophisticated indexing schemes for the 1998-2001 phase of the project. We are currently considering the PARKA knowledge representation system (Hendler, www.cs.umd.edu/projects/plus/Parka/parka.html).

Texts such as manuscript transcripts or public documents are selected based on either specific teacher requests or assessments made by project content specialists. If the document is not in electronic form, it is scanned and OCRed and a bibliographic record is created. At present, there are few texts included in the BLC collection.

Many of the images were selected from the US Archives. In addition to spending scores of hours at the Archives locating and scanning images, images from a CD-ROM provided by the Archives were selected. For each image, a thumbnail GIF file as well as the full-size GIF is stored. For each image, a bibliographic record is created.

Video tapes with time codes are provided by Discovery and these tapes are segmented manually by project staff. Segments are judged to be discrete conceptual units from an instructional perspective and serve as individual video objects for indexing and retrieval purposes. Because these are already highly structured video programs made for instructional purposes (Learning Channel programming), segmentation is straightforward with segments averaging 2 minutes. The segmentation data is then provided to the Discovery team and MPEG 1 encoding is done. A CD-ROM for each program is provided with separate MPEG files for each segment. These files are then used as input to a program developed in the UMCP Center for Automation Research (Kobla, Doermann, & Rosenfeld, 1996) that identifies scene change frames. These frames, stored as GIF files are considered to be to be candidate key frames for the purposes of previews. A directory of potential key frames is thus created for each video segment (between 30 and 80 candidate frames are typical for a two-minute segment). Our present approach is to manually select four key frames from these candidate frames to best represent the segment for video previews that become part of the bibliographic record for that segment. We are exploring ways to automatically select key frames (e.g., the editing production model may provide a principled approach to automatic selection, Hampapur, Jain, & Weymouth, 1995). We are also experimenting with alternative video preview mechanisms such as video wall, fast forward, and parallel windows, and ways to take advantage of textual transcripts for the video. A pilot study on fast forward alternatives demonstrated linear degradation of accuracy on object recognition tasks when fixed sets of key frames for video segments were shown at 1, 4, 8, 12, and 16 frames per seconds. A slightly less pronounced effect was found for gist recognition tasks at these frame rates (Ding, in preparation). Likewise, we are exploring ways to automate the segmentation and indexing processes by taking advantage of transcripts for the Discovery Channel video (we also have access to the less accurate closed-captioning for broadcast programs). Additionally, summary and full transcripts for videos will be available to users.

WWW sites are added to the collection upon recommendation by teachers or project staff only if three conditions are met: they must be clearly labeled as in the public domain; the site must be maintained on an institutional server (e.g., government agency, university, etc.) by an established group (no student sites are included); and the site is fully traversed to follow every link at least one level deep to determine whether possibly objectionable content is referenced. Clearly, these last two conditions are subjective. For sites meeting the conditions, a bibliographic record is created. It should be noted that we aim to facilitate the guidelines and policies that teachers using the Internet in classrooms of the Baltimore City Public Schools follow.

Instructional modules are contributed by community members voluntarily. Modules are created using a module construction component of the BLC system (described below) and consist of materials of any data types organized by instructional guidelines. In a summer training institute during August 1996, teachers and project staff created the first modules. Examples include: Baltimore's environment, the Boston Tea Party, experiments in space, hurricanes, rain forest, and women and war. At present, no peer review process is used since the community is small and we must develop an experience base for developing and managing such modules. In the third year of the project, a community-based contribution procedure is planned that cascades up from peers at the school level to the school district level.

User Access

Access to BLC resources is customized for instructional settings. Thus, access points are based on instructional topics and instructional outcomes, and the interface is designed to support the creation and use of instructional modules that include objects from the BLC corpus. Interface representations and mechanisms are guided by the view that information seeking is a dynamic, and iterative decision-making process (Marchionini, 1995). This view holds that except for known-item searches, information seekers initiate search through a query or by focusing on a subset of the dataset, examine objects rapidly to determine whether to examine them more closely, either reject further examination and move on in the dataset or conduct any number of more focused examinations of the object at different levels of representation. This process continues until the information need is satisfied or satisficed, or the search is abandoned. Note that this view of information seeking leverages organizational schemes that provide many levels of representation for information objects-- ranging from terse but informative surrogates such as titles to increasingly detailed displays. In such schemes it is important to be able to quickly reject objects for further examination and provide the user with useful intermediate surrogates. In the BLC project these surrogates are instantiated as object previews. We believe this perspective is particularly crucial for bandwidth and storage intensive data such as video and for users such as teachers who have little free time for locating new instructional materials.

To support these access perspectives, we have chosen to use a dynamic query interface approach (Ahlberg & Shneiderman, 1992; Shneiderman, 1994) that closely couples the query to results, visualizes the data for highest level of surrogate (categories), and supports rapid and incremental data exploration. The categorical access points (topic and outcomes) present a special challenge since display fields (e.g., starfield in Filmfinder, barfield in Lifelines) are best applied to fine-grained, intervally-scaled dimensions. Our initial solution to this challenge is to combine a hierarchical structuring of data with a bar-graph by data type for each topic/outcome combination. This component of the BLC system is implemented in C++ (CodeWarrior) and will become a Netscape plugin to the BLC gateway.

We considered a variety of attributes to use as filtering variables in the interface. Topics, subtopics, subject (science or social studies), outcome, format, and source (e.g., US Archives, Discovery, WWW, etc.) are attributes that apply across all the objects in the library. Note that all of these attributes are categorical. Many other attributes apply to special types of objects. Length is an interval attribute that may be of interest to users but is format dependent. Although length of video in time units would be most meaningful to users, temporal units do not apply directly to the other formats. Byte length of files to be transferred applies to video (ignoring streaming advantages), images, and texts, but is more problematic with web sites and instructional modules. For web sites, determining exactly which pages must be transferred is difficult, plus sites are dynamic and may change over time. Similarly, for instructional modules, should the byte size of the module itself with only the pointers to data objects or file sizes for objects as well? Certainly, teachers would benefit from knowing how many data objects or better yet how many class periods the module was designed to cover. Moreover, the modules themselves are dynamic and every change would have to be reflected in the underlying indexing information. Other attributes may be very helpful to users but apply only to specific data objects, for example, reading level based on one or more readability indexes would be useful for texts but not applicable to other formats; an approval rating or presence of teacher reflections would be helpful for instructional modules but not applicable to other formats. After some experience accrues, frequency of access (popularity) values may be useful to consider.

Because one of the goals of the project is to influence teaching practice to be outcome oriented, we chose outcome as an attribute for one of the display axes. Based on conversations with teachers, it was clear that topic should be one of the classification attribute for the purposes of display. Thus, the first design decision was to use topics and outcomes as the axes. Because the topics and outcomes are specific to academic subjects, we require users to select science or social studies to determine what type of display is provided. Figure 1 shows a screen for the social studies category with main social studies topics on the vertical axis and social studies outcomes based on recommendations of the National Council for the Social Studies on the horizontal axis. Similarly, outcomes for science are based on recommendations by the National Science Teachers Association. For each main topic/outcome combination, a bar graph represents how many objects for each of the five data types have those attributes. Each bar graph has up to five bars with different colors representing different data types

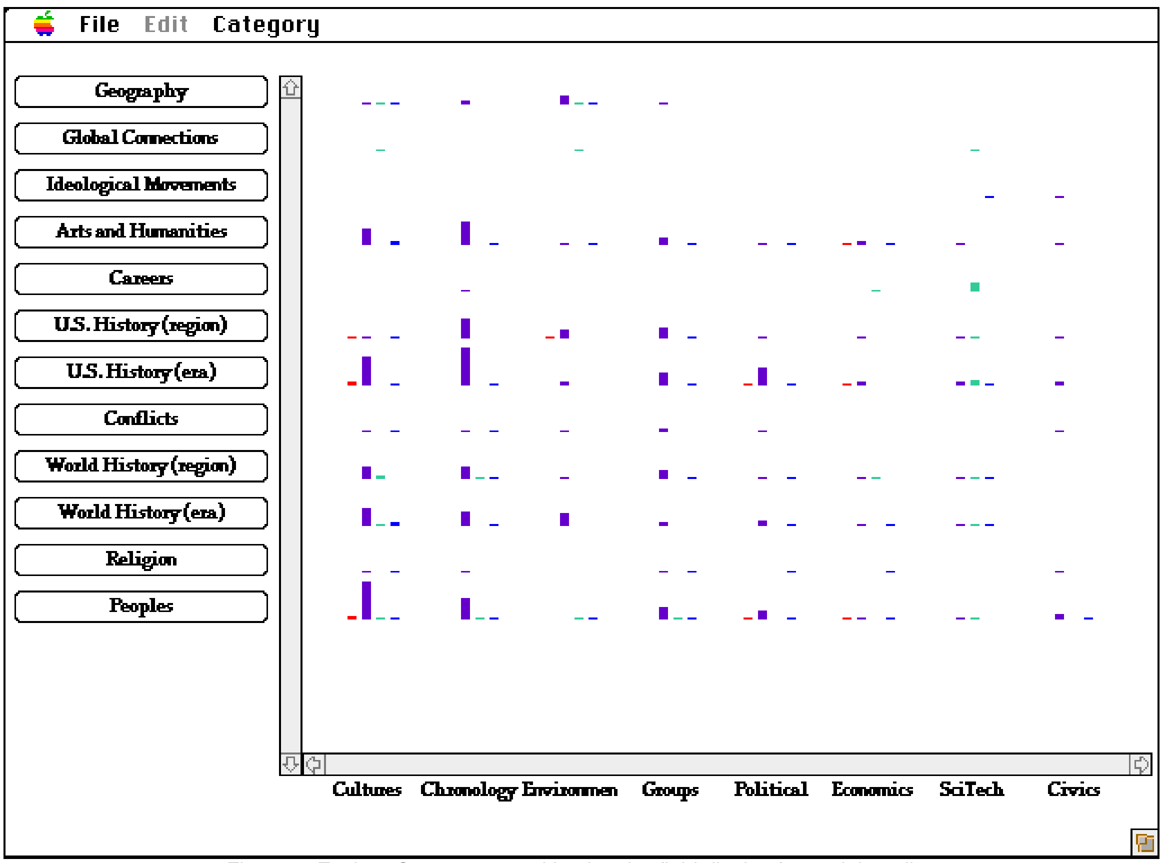

Figure 1. Explore Component multivariate barfield display for social studies

(web site, image, video, text, module). For social studies, there are twelve main topics and eight outcomes, yielding 96 bar graphs for the social studies objects. In Figure 1, there are no web sites, several images, a few video clips, no texts, and no instructional modules on the main topic "World History by region" and outcome "Cultures." Note that the database in this prototype system is sparsely populated with only about 1500 objects

Clicking on the video bar on this graph pops up a list of video clip titles, and highlighting one of the titles ("Human Hunters") yields the display in Figure 2.

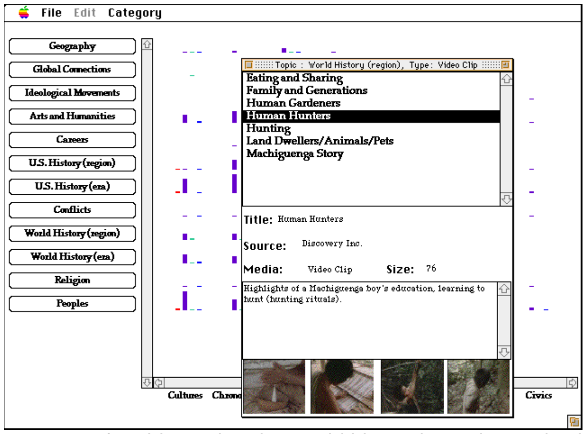

Figure 2. Video surrogate for object related to world history by region and cultures outcomes

These object surrogates are similar to bibliographic records, displaying basic attributes such as source and size (for videos, time in seconds), a brief textual description, and a preview (for videos, four manually selected key frames from the automatically selected key frames). Selecting the record will initiate downloading of the video clip (we are exploring other levels of surrogate between the high-level preview and the full video clip). These records may then be added to modules under construction or displayed as stand-alone objects. Figure 3 illustrates a display for the subtopics under "World History by Region." Note how the bars in the main topic are now dispersed among the subtopics.

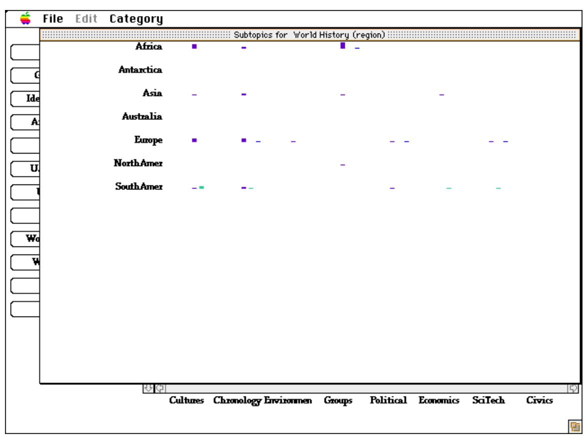

Figure 3. Explore Component multivariate barfield display for social studies subtopic world history by region

mThis first prototype has drawn good reactions from teachers during various demonstrations but has not yet been implemented for their use. There are several additional features to add and some problems with the interface. We have begun to add a specialized attribute for each of the two subject areas; time period for social studies objects and science terms (organic/inorganic). Time will be selected on a slider bar and science categories with radio buttons. Existing objects will be reindexed to include these attributes. Additionally, buttons for adding objects to the modules must be added and some details added to the bibliographic records (e.g., units of size). At present, the bar lengths are treated as relative lengths. Because we expect there to be wide-ranging distributions in the density of objects for different topic/outcome combinations and data types, and the number of pixels available for each bar graph region is constrained (about 40 by 25 pixels for the Macintosh monitors), the bar lengths are implemented as a proportion of the highest number of objects on the screen. For example, the highest bar on the social studies screen in Figure 1 has 80 objects, so a bar representing 50 objects would be 50/80*25+1 or about 17 pixels high. To help users overcome possible confusion between the visual and numeric values, a status display at the bottom of the screen shows the number of items represented by a bar when the cursor rolls over a bar. Whether this is sufficient requires user testing feedback. Another potential problem for users is the fact that many to many relationship indexing is done for objects and attributes. Thus, a single object may appear as an element in several different bars. Because a goal is to explore reuse of data objects and indexing is inherently subjective, we believe this is the best approach but will be certain to discuss this in training and documentation.

Applying and Extending the Library: Module Construction

Finding information objects is only part of what libraries are about. Although physical libraries provide a variety of services to help users interpret and use information found in their holdings, there is a strong privacy ethic that tends to limit how much assistance librarians offer beyond access--that is, what users do with the information accessed in libraries is up to them, thus protecting their privacy while also minimizing requirements on the human resources of the library. Just as special libraries may offer post-access services (e.g., translation, patent investigation, bibliography preparation), digital libraries that are specialized can provide specialized tools and services to assist users in interpreting, using, and communicating what they access. For users of the BLC system, access is only the beginning--although teachers or students could use the exploration component to do on-the- fly searches during class, the main purpose is to help teachers and students be more planful before class begins. Thus, an important component of the system supports the creation of instructional modules that tie topics, outcomes, procedures, and evaluation together. The module construction component of BLC allows teachers (and possibly students) to plan lessons that integrate relevant objects from the library.

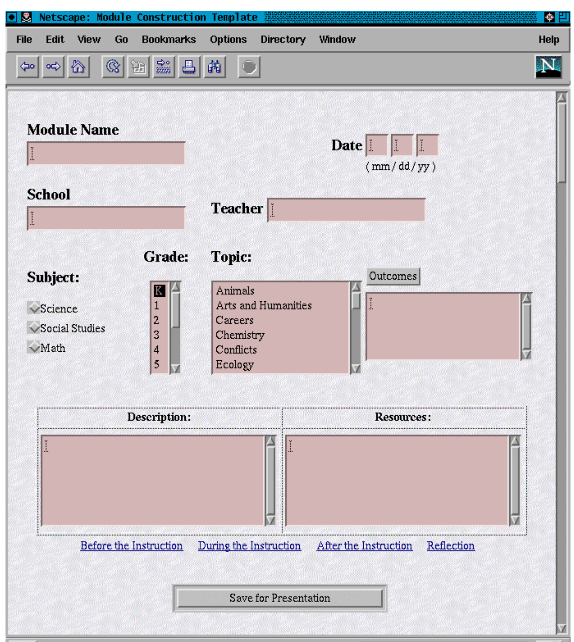

Figure 4. Module Construction Component main screen

This component uses a WWW-based, form driven interface which has five main sections: a general characterization section with a few required fields, a before instruction section, a during instruction section, an after instruction section, and a reflections section. Figure 4 illustrates the main module construction form. Title and teacher name are required but teachers are encouraged to complete as much of the form as possible.

The outcomes button is linked to an electronic version of the Maryland School Performance Assessment Program (MSPAP) outcomes for social studies and science so that teachers can easily link their modules to these outcomes that are assessed each year in every public school in Maryland. These outcomes and accompanying indicators are more extensive and localized than the outcomes used on the horizontal axis of the exploration module which are based on recommendations of national professional organizations. By separating the state standards in this manner, users in other states could easily substitute their specific outcomes and indicators without having to change the exploration or module construction components.

The before instruction section allows teachers to specify the type of learning activity planned, groupings, and type of cognitive operations, as well as make notes about activities and required resources (in particular objects from the database). Figure 5 illustrates this section. The during instruction section allows teachers to specify what students are going to do as well as what the teacher will do. The after instruction section allows teachers to specify evaluation and follow up activities, and the reflections section is meant to allow teachers to comment on the effectiveness of the module and make notes that other teachers might find useful or they themselves might want to consider when using the module another time. Because we want to grow a community, it is important that teachers use the reflections before contributing the module to the BLC corpus.

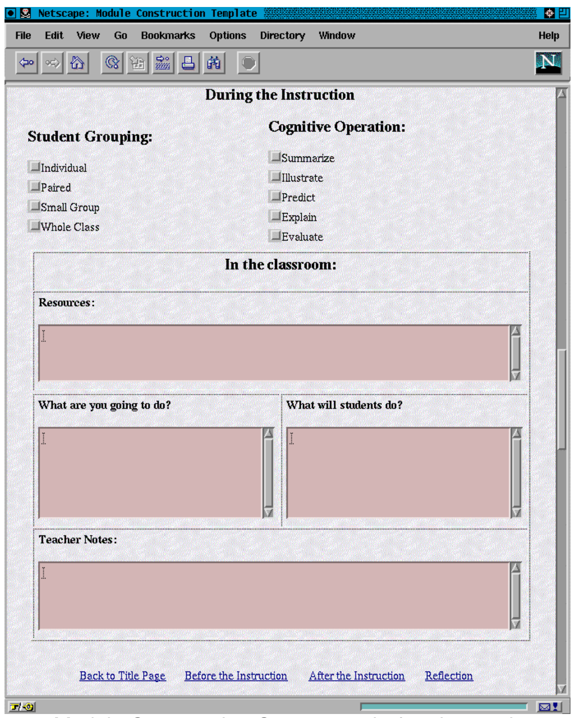

Figure 5. Module Construction Component before instruction section

In addition to the module construction component, a presentation component will allow teachers or students to present a module without all of the instructional details contained in the module. Figure 6 illustrates the first prototype of the presentation component. Based on teacher feedback, this component is being revised to work more like a simple slide show presentation that will be driven by simple forward, back, start, and end buttons so that teachers or students can easily use it during class sessions.

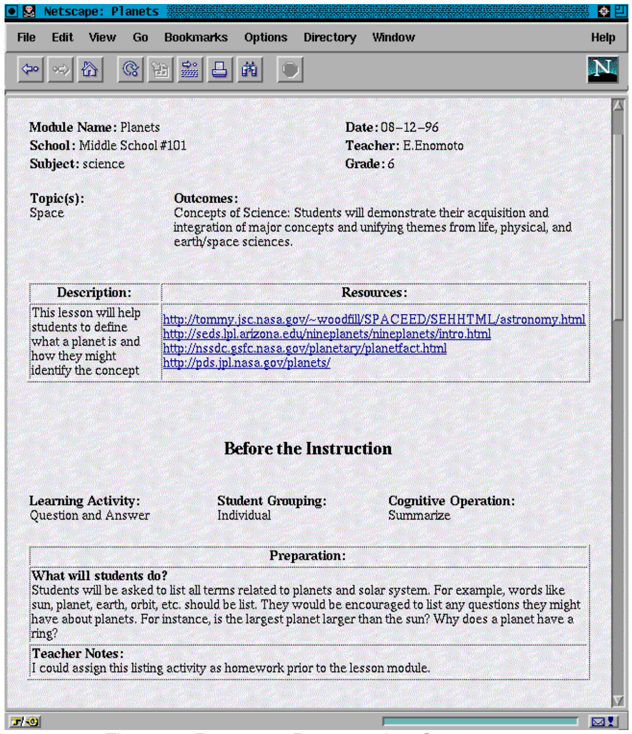

Figure 6. Prototype Presentation Component

System Development & Project Evaluation

The main emphasis here is on the interfaces for object access and usage, however, there are several architectural issues the BLC project must address. First, the objects must be delivered from the BLC server to individual classrooms. The original plan was to lease T1 lines for each of the schools and then use the Ethernet local area network within each of the buildings to deliver content to individual workstations. In the past two years since the proposal was developed, the telecommunications picture has evolved considerably. For the first year of the project, low speed (56kps) frame relay service was provided for each school to establish Internet connectivity and familiarize teachers with networking capabilities. In the first phase of the project, while many of the components of the system are being developed, large hard disks (4 gB) on a teacher workstation in each classroom will serve to store specific modules in use for a few weeks and large files will be downloaded from the Sun SparcStation server over night. This solution seems particularly appropriate given Andreessen's recent comment on replication: "Bandwidth and telecommunications infrastructure cost more than disk storage (home.mcom.com/comprod/columns/techvision/replication.html)." Our plan is to use Starlight video server software to stream video objects from the server to the Macintosh clients once a high-speed solution is determined. For the next phase of the project, we are investigating three alternatives: fiber connections leased from the local phone company, cable modems connected to the cable feed from the cable company that serves the city of Baltimore, and a hybrid wireless solution. In the first case, lines would be leased from Bell Atlantic. We are exploring the possibilities with TCI to provide the cable solution and investigating ways to use Direct PC or other wireless solutions for downlinks. The IBM Interactive Data Carousel solution used in the EduPort project seems particularly interesting as a wireless approach (Chernock, R., 1996; Ruiz, Masullo, & El-Shishiny, in press). The decision on high speed connectivity will be made late in 1997 as the database expands and the first prototype system components have been user tested and ready for revision.

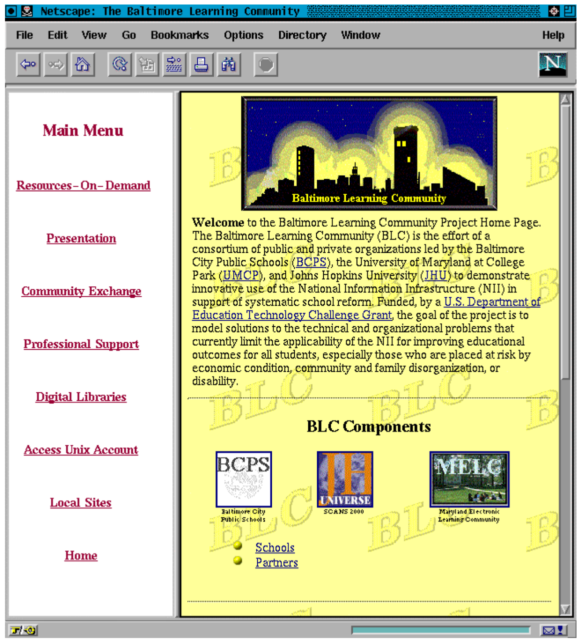

Figure 7. BLC Gateway

The BLC gateway (see Figure 7) includes other components for email, community listservs, video conferencing (planned for the next phase), and links to other electronic resources. Because the success of the project is so dependent on teacher participation, we have provided each teacher with Internet access through a local service provider and a 28.8 modem for use with their home computers. All but a few of the 15 teachers had home computers and those that did not borrowed one of the classroom computers over the summer. In addition to the 2 day summer institute held in the summer of 1996 where teachers used the database at the University of Maryland to create their first instructional modules, inservice meetings at the schools have been held on a variety of topics and graduate students and faculty from the project visit the schools on a regular basis to provide support and document progress. The Discovery Channel has conducted workshops on the use of video in the classroom and video tapes of a variety of their programs have been made available to participating teachers. The intention is to provide a pedagogical basis for using video and other resources beyond the textbooks and materials in the classroom and to develop a community perspective that extends the resources for students and teachers beyond the classroom walls. In addition, we can learn how instructional strategies change when teachers have control over fine-grained video objects (about 2 minute clips) rather than entire programs. A variety of evaluation efforts are underway. Baseline interviews have been conducted with project staff and participants (Enomoto, in preparation), teacher questionnaires were used at the summer institute, the project electronic lists are logged, and observations are made in the different classrooms on a regular basis. We are particularly interested in discovering how teaching behavior evolves as a result of the project and what factors influence community building.

Conclusion

There are few unique research elements of the BLC project. What is unique is how the fruits of research and development are integrated over a fairly long period of time in working school environments. Thus, some of the biggest challenges (as in physical libraries) are social and political rather than technological. Coordinating the efforts and needs of more than a dozen teachers, several administrators, more than a dozen project staff, and hundreds of students requires community building techniques and practice. We fully expect that the work of the first two years will be revised for the later phases of the project--new indexing schemes, updated interfaces, much more data, a more integrated networking solution, and more customized inservice training and evaluation experiences will emerge based on the experience and testing of the first-phase prototypes described here. Perhaps the most difficult challenges and most valuable contributions will be in determining how much human commitment is required to insure that content plus connectivitiy does lead to community.

References

Ahlberg, C. Williamson, C. & Shneiderman, B. (1992). Dynamic queries for information exploration: An implementation and evaluation. *The Proceedings of ACM CHI*, 1992 Monterey CA, (May 3-7) pp 619-626.

Chernock, R. (1996). Disc in the sky. *EduPort Newsletter,* 1(6). Available from Eduport@umlvm.unl.edu.

Ding, W. (in preparation). An experiment on video browsing.

Enomoto, E. (in preparation). BLC Formative evaluation report. (http://www.learn.umd.edu/reports)

Hampapur, A., Jain, R., & Weymouth, T. (1995). Production model based digital video segmentation. *Multimedia Tools and Applications*, 1(1), 9-46.

Kafai, Y. & Resnick, M. (1996). *Constructivism in practice: designing, thinking, and learning in a digital world*. Mahwah, N.J.: Lawrence Erlbaum.

Kobla, V., Doermann, D., & Rosenfeld, A. (1996). Compressed domain video segmentation. *Technical Report CAR-TR-839 CS-TR-3688*, University of Maryland.

Marchionini, G. (1995). *Information seeking in electronic environments*. NY: Cambridge University Press.

Marchionini, G. & Maurer, H. (1995). The roles of digital libraries in teaching and learning. *Communications of the ACM*, 38(4), 67-75.

Nolet, V., Marchionini, G., & Enomoto, E. (in press). Combining Dynamic Query and Full Motion Digital Video in a High Speed Network to Improve Instruction in Middle School Science and Social Studies Classes. *Proceedings of ED-MEDIA 97* (Calgary, British Columbia).

Pea, R. (1996). Computer support for knowledge building communities. In T. Koschmann (Ed.*) Computer support for collaborative learning: Theory and practice of an emerging paradigm*. Mahwah, N.J.: Lawrence Erlbaum.

Ruiz, A., Masullo, M., & El-Shishiny, H. (in press). A regional broadcast-centric educational services solution. Submitted to *IEEE Symposium on Computers and Communications: ISCC '97.*

Shneiderman, B. (1994). Dynamic queries for visual information seeking. *IEEE Software*, 70-77.

Williamson, C. & Shneiderman, B. (1992). The Dynamic HomeFinder: Evaluating dynamic queries in a real-estate information exploration system. In *Proceedings of ACM SIGIR*, 339-346.