Learning and the Digital Library

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ABSTRACT

THE PHRASE "LEARNING AND THE DIGITAL LIBRARY" encompasses two distinct components: learning related to accessing, evaluating, and using the information resources available in this environment and learning related to mastering and building upon the ideas embodied within those individual resources. Educators and system designers must draw upon research, theory, and practice from fields concerned with both these components in order to help children achieve the maximum learning benefits afforded by the digital library. This article draws upon selected research from two such fields—information studies and instructional technology—in order to present a range of ideas related to using the digital library as an environment for school-based learning. Although the two fields overlap, information studies provide insights primarily about the contextual and relational aspects of using the digital library, while instructional technology provides insights primarily about learning with the various media formats encompassed within this rich and complex venue. "Information literacy," an area that incorporates concepts from both areas, provides a useful overarching framework for considering the digital library as a learning environment.

INTRODUCTION

There are few doubts about the potential of the digital library for providing unprecedented access to information and ideas. There are numerous doubts, however, about the potential of this rich and still-

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mysterious venue for providing an optimal environment for learning. In fact, the very strengths of the digital library—its limitless information, variety of formats, affordance of unconstrained navigation, and support for combining material in myriad ways—are the sources of these uncertainties in formal learning environments. We know little enough about how to foster higher-level learning with "traditional" collections of print and nonprint materials. How, then, can we foster such learning in the vast and untracked terrain of the digital library?

Research in information studies traditionally focuses on accessing information rather than on learning from it, but the emergence of electronic information resources (EIRs) has been a catalyst for a range of work on the relationship of these resources specifically to learning. In addition, insights on learning and media accumulated by the field of instructional technology provide another important perspective on learning in electronic environments. Research and theory from both these fields suggest both caveats and opportunities related to children's prospects for learning in the digital library. Placing these insights within the larger context of "information literacy" provides a framework for understanding and addressing a variety of issues related to learning in this exciting new venue. The purpose of this article is to draw upon selected research and theory across this spectrum in order to present an array of insights about enhancing the potential of the digital library as an environment for higher-level learning in the school. Reflecting our current limited knowledge about this complex topic, the article is introductory rather than exhaustive and is intended to offer a starting point for further discussion and research.

The Digital Library as a Venue for Higher-Level Learning

Wozny's (1982) investigation of ninth-graders' use of online bibliographic databases in connection with an independent research project is one of the earliest studies in this field to draw attention to the potential of electronic information resources not just to help young learners access information but "to introduce students to a broader world of information" (p. 40) and to provide "a new opportunity for assisting students in developing search strategies" (p. 42). Ensuing years have seen a variety of other works designed to explore the broad relationship of EIRs to learning and particularly to the mastery of the concepts and skills required for conducting research (e.g., Aversa & Mancall, 1986; Callison & Daniels, 1988; Crane & Markowitz, 1994; Lathrop, 1989; Mancall, 1984; Neuman, 1993, 1995a, 1995b). Each of these works—along with a variety of others—has had a role to play in shedding light on the complexities of learning with and through EIRs. Today, that light might profitably be focused on learning and the digital library.

Mancall (1984), for example, noted the importance of teaching logic

and critical thinking skills in order to help students use online databases profitably. Aversa and Mancall (1986) suggested that students should be taught online searching specifically so that they can become knowledgeable about information and about how to develop and refine their strategies for finding and using it. Callison and Daniels (1988), after working with forty-one juniors who searched for information on a variety of topics in a commercial EIR, noted that "the value of the online search experience for the high schooler" might well go beyond the acquisition of basic experience with using the technology to "the challenge to make information-use decisions based on facts, relevancy, recency, and authority" (p. 180). Lathrop's (1989) survey of seventy-three secondary-school librarians in nineteen states focused specifically on online information retrieval as a research tool and addressed (among other concerns) instructional objectives, student training, and curriculum uses. More recently, Crane and Markowitz (1994) detailed a three-level model for teaching critical thinking through online searching, while Neuman (1993, 1995a, 1995b) identified a number of curricular and instructional issues to be addressed in helping high-school students become competent and credible researchers with EIRs. All this work reveals a growing awareness that EIRs provide a critical venue for helping students learn concepts and skills that are essential in the information age—abilities to access, evaluate, and use information to build knowledge, to think critically, and to solve problems. The digital library, which provides an even richer and more complex environment than the individual components investigated in these studies, offers an even more extensive venue for helping students develop these essential abilities.

Neuman's (1995b) national Delphi study related to learning and online and CD-ROM databases, for example, reported a number of findings that can readily be extrapolated to the wider world of the digital library. The Delphi panelists (twenty-five library media specialists who are experts in using these electronic information resources with high school students) rated over 200 statements, including several that specifically addressed the importance of using EIRs to enhance students' research skills. Ratings of two statements in particular highlight the importance the panelists assigned to this function: "A goal of a database curriculum should be to help students master the higher-order thinking skills involved in designing, conducting, and interpreting research" and "Database searching should be part of a formal research offering that covers the nature and processes of research, various tools, etc." These two statements were among only six from the entire study that garnered final means of 4.0—"perfect scores" on the instrument's scale of 0 to 4. The panel's unanimous agreement with these statements as well as Neuman's summary for the full study underscores the importance of using EIRs as ven-

ues to foster higher-level learning: "The results confirm that the major issues related to schools' use of online and CD-ROM databases involve their role in students' development of the higher-order thinking skills necessary to plan, design, and conduct competent and credible research in the electronic information age" (Neuman, 1995b, p. 284).

Research from Information Studies: Students' Interactions with Components of the Digital Library

Information studies research has also addressed the complexities of students' interactions with various kinds of electronic information resources in an attempt to identify successful and unsuccessful strategies and, further, to suggest design elements that might enhance students' use of these tools (Large et al., 1994a, 1994b; Liebscher & Marchionini, 1988; Marchionini, 1989; Marchionini & Teague, 1987; Neuman, 1993, 1995a, 1995b; Perzylo & Oliver, 1992; Small & Ferreira, 1994; Solomon, 1993, 1994). Marchionini's continuing focus on students' mental models as they use EIRs has led to important insights related to both elementary (Marchionini & Teague, 1987; Marchionini, 1989) and high-school (Liebscher & Marchionini, 1988) students' effective manipulation within these environments—and, by extension, within the digital library. Large et al.'s, Perzylo and Oliver's, Small and Ferreira's, and Solomon's work on elementary students' use of particular EIRs provides further insights that can be extended to learning and the digital library for this group, while Neuman's studies of high-school students' use of these resources suggests such insights for older students.

Elementary and Middle School Students and the Digital Library

Marchionini and Teague (1987) were among the first to explore elementary students' use of electronic information resources, and Marchionini's finding that children as young as third- and fourth-graders "could successfully use [Grolier's] full-text, electronic encyclopedia with minimal introductory training" (Marchionini, 1989, p. 64) is heartening to teachers and library media specialists charged with helping their students master the textual components of the digital library. Large et al. (1994a) reported similar findings with sixth graders, investigating these children's use of Compton's multimedia encyclopedia and noting that they were able not only to navigate the database effectively but also to determine which alternative path (menu, keyword searching, or title browsing) was most efficient for retrieving verbal information for a particular search task (judged as simple or complex according to the number of possible search terms). Marchionini's notation that the students' strategies in a text environment tended to be heuristic and interactive suggests that children have a natural affinity for the kind of exploratory

and self-directed learning that is particularly well-suited to the digital library. Large et al.'s conclusion that students needed little training to navigate within a multimedia venue—one that included not only text but still images, sound, and video sequences—is also encouraging regarding students' independent learning in the digital library.

Large et al.'s work as well as the work of Perzylo and Oliver, however, raises questions about students' ability to make productive use of the information that renders multimedia environments unique—at least for traditional classroom assignments. Large et al. (1994b) found that multimedia seemed to be more effective for leading to students' recall of simple topics than complex ones and noted that "in general the multimedia group failed to benefit fully from the dual coding of visual and verbal information" (p. 526). Perzylo and Oliver (1992) found that sixth graders were able to navigate the components of National Geographic's *Mammals* effectively but were hampered in their use of much of its material for their "summary papers" largely because they lacked the means and strategies for recording and incorporating the nontextual components that carried much of the information they sought. Students preferred to access the sound, video, photographic, and graphics information in the database—in that order—and read and digested only that textual information that was "brief in its extent and . . . selected intentionally [such as] the photo captions and the hypertext descriptions" (p. 237). For their assignment, however—a traditional written report—students used virtually no information but the textual material they were able to print out (primarily an essay) and incorporated other forms of information only through references in their narratives. Clearly, both the text-based nature of the assignment and the product's lack of printout capability for anything but textual materials all but ensured that students would not be able to use the multimedia information effectively for this task. Nevertheless, the researchers' conclusion that the students' performance reflected not only these factors but the fact that "students appeared to have no skills or knowledge in seeking and recording information from other than textual sources" (Perzylo & Oliver, 1992, p. 238) raises important cautions about the use of multimedia components of the digital library for learning.

Small and Ferreira's (1994) findings reinforce these cautions: these researchers found that middle schoolers (sixth through eighth graders) who used a print resource tended to take written notes as they read and engaged in more "extracting" behaviors than did comparable students who used a multimedia resource. The latter group, who reported that they liked the visual and sound components of the interactive videodisc used for the experiment, generally took only "mental notes" and performed more "browsing" activities. While the study did not address the relative information-gathering success of the two groups, it did note that students rated the multimedia source significantly higher than the print

one on such factors as "accessibility, accuracy, comprehensiveness, consistency, controllability, currency, ease of use, organization, reliability, and understandability" (pp. 100-01). This disconnection between students' preferences for multimedia formats and their inabilities to mine them for in-depth information suggests that students and teachers alike must develop new conceptions of the best ways to access, evaluate, and use multimedia information for learning. The strategies that teachers and students must use to optimize learning through the World Wide Web, for example—whose power stems largely from its ability to provide information in formats other than text—are still to be discovered.

Solomon (1993), too, investigated children's use of a particular kind of electronic information resource—in this case, the OPAC. Like Marchionini, he discovered that elementary students were generally successful in their use of this text-based EIR and, further, that they became increasingly proficient as the school year progressed and they learned to maneuver more and more effectively within this environment. Unlike Marchionini, however, Solomon set out to identify the details of students' interactions with the OPAC so that he could suggest guidelines for designing these EIRs to enhance students' opportunities for success. His results include a delineation of the reasons for students' breakdowns (i.e., failures in retrieval) that provide important insights into the relationship of OPAC use to learning. Solomon identified breakdowns in three kinds of capabilities—knowledge of specific skills, knowledge of rules, and contextual knowledge—that explained students' failures in OPAC use. The implication, of course, is that students must master these capabilities to operate effectively in this kind of environment. First, they must understand basic concepts related to reading, spelling/keying, and the nature and uses of an OPAC. Second, they must understand the OPAC's rules of syntax (e.g., with regard to spacing and punctuation); query formation (e.g., the use of nouns and plural forms); and focus (e.g., differentiating among an author, subject, and title search). Finally, they must understand how to monitor an OPAC response and to take appropriate action, based on their content knowledge and their understanding of how the OPAC works, to proceed successfully.

In a later paper based on this initial study, Solomon (1994) further illuminated the relationship of OPAC use and learning by describing the connection between students' proficiency with the OPAC and the kind of instruction and assignments that different groups of students received. Solomon noted that one group had received clear-cut assignments ("Turn in a written report with the following pieces of information on your state") that allowed them to complete the task simply by entering the name of a state (e.g., Alabama) and retrieving pertinent information. While this group had a high success rate with the OPAC, "the lack of challenge in their searching limited what they discovered about information retrieval.

[They], as a result, were less able to recognize and respond to breakdowns than other students who had more variety in their OPAC experiences." These other students, who "were given assignments that required more in-depth [content] knowledge and more creative control actions at the OPAC . . . began to develop strategies that employed broader, narrower, and coordinate terms that would help them identify additional sources" (p. 47). Solomon concluded that "the challenge of assignments that encouraged children to build on their interests or investigate subjects in some depth carried over to their information retrieval behavior at the OPAC. They needed to move beyond the simple subject search to discover, learn, and try many strategies to get information on their interests and to overcome OPAC breakdowns" (p. 47). Clearly, Solomon's insights about the relationship of curriculum and instruction to students' levels of learning with an OPAC can be extrapolated to the world of the digital library: if a sophisticated curriculum and creative assignments can enhance higher-level learning with such a basic tool as an OPAC, how much more important must these factors be in facilitating such learning in this richer and more complex environment?

High School Students and Text-Based Materials in the Digital Library

One of the earliest studies of high school students' use of electronic information resources was Liebscher and Marchionini's (1988) comparison of ninth graders' "analytical" (Boolean) and "browsing" searches in Grolier's full-text CD-ROM encyclopedia, which established that both groups performed successfully and relatively equally in terms of the mean numbers of search terms used and relevant articles retrieved. Their study raised interesting questions about the application of information retrieved to a learning task, however, because of their finding that the "analytical" group received higher grades on their final essays than did the "browse" group. Speculating about the relationship between the amount of planning required by each group at the query formulation stage and the subsequent "payoff" in terms of information use, the researchers analyzed the prepositional phrases in the students' final essays. They found little correlation between a student's grade and the overall number of such phrases—but they did find an "inverse correspondence between grade received and number of nonrelevant prepositional phrases" (p. 230). The authors theorized that students who used the simple browse strategy might have been unwilling to discard irrelevant information they had gleaned during their searches and that the "less[er amount of] internal organization of information . . . required at the query formulation stage" might have interfered with these students' abilities "to discriminate as well as [the analytical group] between relevant and nonrelevant information" (p. 230). Liebscher and Marchionini's questions about students' abilities

to organize information in a way appropriate to the assignment—even within the restricted environment of a CD-ROM encyclopedia and for the limited task of using that information in a brief essay—raise more substantial concerns about the abilities and strategies students will need in the more diverse and less structured world of the digital library and with the kinds of products to which its information might be applied.

Neuman's studies of high school students' interactions with online and CD-ROM databases (1993, 1995a, 1995b) also attempted to identify the relationship of a particular class of electronic information resources to student learning. The original study, an extensive naturalistic inquiry of ninety-two freshmen's and sophomores' interactions with eighteen online and seven CD-ROM databases, yielded insights into the details of students' successes and failures in using these resources that are particularly salient to learning in text-based components of the digital library. Further analysis of these data revealed the details of basic differences between the structures inherent in databases and the conceptual structures that students bring to searching—differences so compelling that they seriously hampered students' independent use of these resources (Neuman, 1995b).

High school students, of course, are novices—novices in their understanding of research and its methods, in their familiarity with the topics they study, and in their development of the persistence and flexibility that characterize the mature adults for whom most online and CD-ROM products (and most components of the digital library) are designed. Fairly minor symptoms of these students' conceptual naïveté involved their frequent choices of inappropriate databases and their regular pattern of searching for authors in subject indexes and for titles in author indexes. Much of this, of course, reflects the nature of adolescent behavior—choosing whatever workstation happened to be available and beginning a search without paying attention to the information on the screen—and such difficulties can be overcome with patience and instruction. Others, however, suggest deeper problems. One student, for example, looked for articles on "moonshine runners" in a resource that dated from 1982 and explained that the topic was missing from the database because moonshine running was illegal, not because he was looking for historical material in a database of contemporary information. More seriously, a number of chemistry students included items related to *organic* chemistry in their bibliographies for papers on topics in *inorganic* chemistry—not because they were padding their bibliographies but because, as their teachers concluded, these gifted freshmen were unaware that chemistry and chemical information are organized into two branches. If students are stymied at such basic levels and in such simple resources, how will they navigate effectively—let alone efficiently—in the more complex world of the digital library?

The data also revealed an incompatibility between students' needs and the complexity of the resources available to them. Noting that CD-ROM databases are often too simple and online ones too advanced seems almost too obvious for a scholarly observation. But the disparity between the needs of these students and the nature of the information in their electronic information resources was in fact a serious *conceptual* obstacle to the students' effective use of these resources for learning. Most students—even advanced ones—need basic information related to curricular needs rather than either popular renditions or reports of cutting-edge research results. Thus, if the digital library is to be used to help the majority of students (1) master aspects of curricular content, and (2) develop the research skills necessary not only to complete school assignments but to serve as the basis for lifelong learning, then it must include information that is at an appropriate level of complexity both for students' levels of knowledge and for students' tasks. That is, to foster learning, the digital library—like any library—must include a range of resources to meet the needs of a range of users. While Internet access to "world-renowned" experts and their work has excited both educators and students, it is also important to make room in the digital library for information that is conceptually accessible to, and useful for, a student audience whose interests, needs, abilities, and goals make them a truly unique user group. Both the students and the adults in this study called for such basic EIRs as lists of textbooks and young adult trade books on curricular areas and for the creation of subject-specific EIRs that include academic information written for high school students.

A more interesting—and difficult—conceptual issue is the incompatibility between students' knowledge bases and conceptual structures and those inherent in databases. As novices, most students lack the vocabulary, the conceptual schemata, and the cognitive flexibility enjoyed by the experts for whom the majority of digital resources are designed. In this study, students' inability to generate synonyms, combined with their naïveté about how electronic information resources are structured, often frustrated their ability to use even self-contained CD-ROM resources effectively. Extrapolating this situation to the larger world of the digital library raises concerns about how productively students might use this world for learning. Superimposed on the difficulties inherent in any keyword-searching system, how will students' linguistic and conceptual naïveté affect their chances of productive searching?

Students' limited command of synonyms reflected their inexperience with many of the ideas that adolescents go to school to master. One student's exasperation illustrates the problem: "You have to find a synonym. But if you don't know about [a topic], then how are you going to get a synonym?" How, indeed, are students going to find the words and generate the ideas they will need to access information across the digital

library? Words are keys to concepts, and students' limited vocabularies suggest a conceptual immaturity as well as a linguistic one. In a self-contained electronic information resource like a CD-ROM, a built-in thesaurus similar to those routinely found in word-processors could have helped by giving students access to information through vocabulary—and, therefore, concepts—that did not exist in their own conceptual structures. But no such tool existed in the CD-ROMs let alone in the online databases that these students used. Extrapolating the issue beyond this limited environment makes it even more complex because it raises questions about how students can access the most relevant and appropriate information across multiple resources without some mechanism that will expand their vocabularies and conceptual schemata. Lack of knowledge can thwart even simple explorations in subject areas students might want (or need) to study, and these novices might not even be aware that they had missed major and critical information.

Even beyond the difficulties engendered by their limited vocabularies, students' naïve—and often inflexible—conceptual structures about their research areas also hindered their ability to use the text-based electronic information resources in this study. First, it is important to note that the students' structures seemed to reflect almost exactly the structures imposed by curriculum categories in general and by teachers' assignments in particular: as school and public librarians well know, if the history assignment is a research paper on the Civil War, then the phrase "Civil War" may represent the students' entire understanding of the research task, at least at the beginning of a project. Not surprisingly, the students in this study were not always able to exceed the boundaries imposed by a teacher's explanation of a task. Also not surprisingly, without intervention, the students flailed about in both online and CD-ROM resources just as unproductively as students often do when they use "traditional" reference sources.

Discussing the individual resources themselves, students complained that "there are different categories than what you really want" and that they could not search either for such broad concepts as a particular decade (e.g., the 1960s) or such narrow ones as a particular year (e.g., 1865). Predictably, CD-ROM searches for such topics as "World War II," "Catholics in the 1950s," and "one-room schoolhouses" all proved fruitless. Unable to create conceptual categories that matched those inherent in the EIRs, students frequently gave up their searches. To succeed in the broader environment of the digital library, students will clearly need to develop a sophisticated understanding of the nature of information and of the ways it can be organized and explored.

One boy's search for "Vietnam-era draft evaders" illustrates students' conceptual naïveté as well as an even more complex problem: the conceptual rigidity with which some students approached their task. Using a

CD-ROM index, the boy tried "Vietnam" repeatedly, even when the word failed to generate any hits. After considerable prodding from the researcher, he finally tried another approach: he entered "draft" and found a subhead "draft resisters" and a sub-subhead for Vietnam. Interestingly, even though this tack enabled him to find his subject, he continued to insist—as he had throughout this session—that "draft" *should have been* a subhead under the main heading "Vietnam." It seemed clear, first, that he did not understand that information can be organized in more than one way and, second, that this naïveté made him incapable of adjusting his own conceptual hierarchy to find an article independently. Without the outside intervention that he needed to succeed, he probably would have walked away from his task—as many students did—convinced that the EIR held nothing for him.

This student was not alone in his inability to transcend the initial understanding he had brought to his task. Students complained about prompts that asked for more specific search requests—"There was no way I could make mine more specific"—and recommended more general categories. Students also complained, however, about categories they felt were too general: "I thought the [headings were] way too general for some of the topics that we needed to use" [note the phrase "topics that we needed to use"]. Clearly, even in this constrained environment, there was a need to bridge the gap between students' conceptual structures and those inherent in databases. Within the larger world of the digital library, how can educators help meet students' need for flexible traversal of the barriers separating general and specific topics within those categories? Faced with possibilities not only within but across electronic information resources, how will these novices acquire the conceptual depth and flexibility necessary to find accurate and relevant information efficiently and effectively?

In summary, it seems clear that research from information studies has confirmed that the digital library is an essential venue for learning the concepts and skills necessary for conducting research and handling information in the information age. Moreover, this research has also indicated that elementary, middle school, and high school students can indeed profit from their use of such discrete components of the digital library as electronic encyclopedias, OPACs, and online and CD-ROM databases. Studies have also indicated, however, that looking closely at the details of students' interactions with these components raises significant questions about how to maximize electronic information resources for learning.

Some of this research intentionally incorporates insights from another field—that is, instructional technology—in order to address these questions. Research situated directly within that field offers additional avenues for further research into the use of the digital library as an envi-

ronment for learning. In particular, insights from the segment of the field that is concerned with designing instructional materials suggest ways in which components of the digital library might be organized and developed to enhance their potential for learning.

Research from Instructional Technology: Learning and Media

Interest on learning and media dates at least from the early part of the century when "educational museums" were created to house such audiovisual aids as stereoscopic pictures and lantern slides. In the ensuing years, each new technology in turn has taken its place in the march toward more sophisticated and more integrated learning media: instructional film, instructional radio, instructional television, programmed instruction, computer-based instruction, and now a medley of multimedia environments. Formal research programs emerged in the 1940s and 1950s, with investigations of how military training films could be adapted to civilian instruction. Over the years, the learning potential of each new media format—how to identify that potential and how to enhance it—became the central focus of researchers' agendas.

Until the last decade, most of the research in instructional technology—as in education in general—was grounded in behaviorist learning theory. Decades of studies conducted under this paradigm, however, produced results related to learning and various media formats that were, at best, equivocal (see R. C. Clark's 1983 article for the classic and compelling criticism of traditional instructional technology research that jolted the research community). Currently, instructional technology research and development are grounded in cognitive learning theory—which, of course, now undergirds research and practice throughout the teaching and learning community. This new theoretical focus, combined with more sophisticated research methodologies, offers strong new possibilities for understanding the nature and processes of learning in the digital library.

Theoretical Foundations for Research on Learning and the Digital Library

Explorations of the relationship of cognitive theory to instructional technology have in fact co-existed with behaviorist ideas in the instructional technology community for years, and the field has a long history of drawing on both traditions to explore the relationship of media and learning. For example, Robert Gagne's (1977) *Conditions of Learning*, originally published in 1970, became a classic when its third edition interwove principles from cognitive theory with those from instructional systems design. Other classic works in the field have also been reconceptualized and updated to reflect the most current understandings of how people learn.

Of particular theoretical significance to questions about learning and

the digital library is the work of Robert Kozma (1991), whose article entitled "Learning with Media" crystallized and expanded many of the ideas that had been circulating in the instructional design community and established the foundation for conducting instructional technology research within the cognitive perspective. In this seminal work, Kozma described learning as an active, constructive process and defined "learning with media as a complementary process within which representations are constructed and procedures performed, sometimes by the learner and sometimes by the medium" (p. 179). As it has for all of instructional technology research, Kozma's review of research on learning with books, with television, with computers, and (briefly) with multimedia environments offers an important conceptual framework for research on learning and the digital library.

Kozma postulated that each of these media formats is distinguished by a cluster of characteristics that, taken together, make the particular format more and less suitable for particular kinds of learning tasks. The stability of print, for example, supports serial and sequential processing and the development of static (although not necessarily simple) mental models; the motion of video media and their concurrent presentation of information through several sensory channels support simultaneous processing and the construction of mental models that include dynamic and procedural components. The transformational ability of the computer—its ability not just to present information but to transform it from one symbol system (like numbers) into another (like a bar graph)—supports the learning of underlying abstract rules and principles that define the structure of knowledge. Multimedia environments, which combine the characteristics of all these individual media formats into an integrated and expanded whole, may help learners build and analyze mental models of complex problem situations. Kozma (1994) was quick to admit that "the cognitive effects of the more recently developed environments are speculative" (p. 206), but in a later article he offered his conclusions and insights as an argument for reframing instructional technology's longstanding debate on the contributions of media to learning:

> Perhaps we should ask, what are the actual and potential relationships between media and learning? Can we describe and understand those relationships? And can we *create* a strong and compelling influence of media on learning through improved theories, research, and instructional designs? (Kozma, 1994, p. 233).

Kozma's three questions as well as his recommendation that researchers explore "specific ways in which media capabilities may be used to influence learning for individual learners performing particular tasks in specific content areas" (p. 237) offer particular guidance for research related to learning in the digital library—the largest and most complex multimedia environment learners have ever encountered. His inference

that we are just beginning to ask the most important questions and to explore the most significant relationships suggests that the digital library is an exciting "learning environment" for theoreticians, researchers, and developers as well as for students.

Work from information studies described earlier provides some insights into the nature of student learning in that environment and the questions that remain to be answered: Liebscher and Marchionini (1988), Neuman (1993, 1995a, 1995b), and Solomon (1993, 1994) all suggest important capabilities that students must acquire to use text-based electronic information resources successfully; Large et al. (1994a, 1994b), Perzylo and Oliver (1992), and Small and Ferreira (1994) perform the same function for multimedia materials. Instructional technology—and particularly instructional systems design—provides insights into how components of that environment might be designed to foster that learning.

Designing Components of the Digital Library

One of the enduring works in instructional technology is Malcolm Fleming and Howard Levie's (1978) *Instructional Message Design: Principles from the Behavioral Sciences*—re-issued in 1993 as *Instructional Message Design: Principles from the Behavioral and Cognitive Sciences.* The 1993 edition combines findings from both traditions of learning theory to specify over 300 research-based guidelines for designing instructional presentations in various print and nonprint formats—and over 200 of these address issues that can be applied to creating components of the digital library. This collection of principles for designing materials to enhance motivation, perception, general learning, concept learning, and problem-solving is clearly relevant to enhancing the potential of those components as venues for learning.

Even such simple principles as "Purely decorative pictures should be used sparingly" (Fleming & Levie, 1993, p. 89) and "Logically organized text is better remembered than poorly organized text" (p. 208) provide useful insights about how components of the digital library might be organized and presented to increase students' likelihood of learning in this environment. More complex principles—such as "The acquisition of unfamiliar content can be improved via familiar examples, analogies, and metaphors, while such strategies are less essential for familiar content" (Fleming & Levie, 1993, p. 215) and "The presentation of visually richer and more realistic best examples leads to a richer and better consolidated prototype resulting in increased transfer" (p. 244)—can also be mined for their applicability to creating elements of the digital library. Because these principles focus on designing *instructional* rather than *informational* presentations, they offer a critical perspective on preparing segments of the digital library that will be used by students. Applying such "design for learning" axioms as well as guidelines for ensuring opti-

mal access and retrieval seems a fundamental prerequisite for enhancing the learning potential of the digital library.

A number of today's instructional technology researchers are exploring what are known as "open-ended learning environments"—settings that seek to integrate instructional and informational components and in which students perform tasks and processes that are similar to those they must perform to learn within the digital library. Michael Hannafin, who has emerged as a leader in this effort, describes a range of individual settings that researchers are developing and testing in order to enhance our understanding of how students learn in electronic environments that do not just present concepts to be learned but that incorporate extensive information resources. "Macro-level environments" include both rich collections of resources and tools students use to explore them "to pursue interests or needs beyond the parameters typically provided in isolated lessons" (Hannafin, 1992, p. 58); "micro-level environments" offer similar arrays of materials but focus within more discrete domains. "Generative environments," such as the *Jasper Woodbury* series created by the Cognition and Technology Group at Vanderbilt University, consist of scenarios with embedded information that students must identify, evaluate, and manipulate to solve problems. "Mathemagenic environments" support access to various representations of content in a particular area (often through hypermedia links) and allow students to "move rapidly among networks of concepts [and] to construct their own sets of relationships within the network" (p. 59). According to Hannafin, these various settings can support either goal-directed learning—as do traditional instructional media—or exploratory learning. The question for instructional technology—clearly an echo of Kozma's (1994) questions noted above—seems to be how to adapt traditional design theories and methods to the creation of environments that can support both kinds of learning, perhaps within the same "package." The question for those who are concerned with learning and the digital library is how to extrapolate the insights gained through research in these individual settings into a wider world that includes many discrete resources and also requires traversal across and among them.

A great deal of discussion in instructional technology has focused on these settings, which have proliferated in recent years. Goodrum, Dorsey, and Schwen (1993), for example, described the conceptual and practical difficulties in designing an "enriched learning and information environment" that accommodates the difficulties that Perkins (1991) had identified for students operating within such a setting: high cognitive load, increased responsibility for managing their own learning, and need to adopt an unfamiliar learning process. Scardamalia and her colleagues (1989, 1992) have worked for years on the development and refinement of CSILE—"Computer-Supported Intentional Learning Environment"—a

shell that allows students to create their own knowledge base related to classroom instruction by working collaboratively in an electronic environment to generate hypotheses, ask questions, and revise their understandings of that information. Rieber (1990, 1996) has explored how both animation and elements of simulations and games can enhance students' abilities to focus on and learn from multimedia "microworlds." In their exploration of the assumptions, methods, and implications for learning inherent in the various kinds of open-ended learning environments, Hannafin, Hall, Land, and Hill (1994) noted the lack of compelling empirical evidence of how open-ended learning environments influence learning and, further, discussed the difficulty of obtaining such evidence: these environments are "designed to promote fundamentally different kinds of learning" than the field is used to studying; its tools for understanding "different kinds of learning goals" and for "assessing the successes or failures of such systems" are underdeveloped; and its "design science for such systems" is "very weak" (p. 52). Clearly, the authors might be describing the state of our knowledge about designing materials to enhance learning within the digital library.

Thus, while instructional technology research is following Kozma's dictum to ask new questions, the field is less able to provide new answers. In the tradition of Fleming and Levie (1978, 1993), however, Hannafin and his group have compiled a set of empirically based guidelines for designing interactive multimedia that might provide some insights into how components of the digital library might be designed to enhance learning (Park & Hannafin, 1993). In fact, their explanation of what they mean by "interactive multimedia" might stand as a definition for the digital library itself:

> Interactive multimedia dynamically link and manage organized nodes of information containing multiple symbol systems and images within a given medium or across different media. [They] provide user-directed, nonlinear methods for organizing and accessing information . . . ; support access to knowledge according to individual demands . . . ; permit direct access to individual elements contained in large databases . . .; and provide user-centered interactive environments. (p. 63)

Many of their twenty principles, along with corresponding implications for design, stress the importance of the organization of information and could be readily applied to designing components of the digital library to enhance their learning potential. Note, for example, Principle 4: "Knowledge to be learned needs to be organized in ways that reflect differences in learner familiarity with lesson content, the nature of the learning task, and assumptions about the structure of knowledge" (Park & Hannafin, 1993, p. 70). Or the implication derived from Principle 16, which describes the importance of using visual representations to help

structure students' knowledge and experience: "Provide concept maps to indicate the interrelationships among concepts and hypermaps to indicate the location of the learner relative to other lesson segments" (p. 78). Such aids to structure and orientation within the digital library could clearly enhance students' success in this environment. These and other heuristics suggested by Park and Hannafin directly address such "information retrieval" issues as the importance of students' conceptual structures to successful searching noted above (Neuman, 1993, 1995a, 1995b).

For researchers, teachers, and school library media specialists concerned with learning in the digital library, this description of the state of the art related to understanding and creating learning environments raises both hopes and cautions: while it is heartening to see the insights and advances that can be gleaned from instructional technology, we are still left with the fundamental question of how we can help students exploit EIRs individually and in the aggregate to achieve higher-level learning. Instructional technology might provide insights about learning within specific environments, but the field has not extrapolated its findings beyond those limited settings. A comprehensive approach that integrates these findings with findings from information studies is necessary to provide a conceptual framework for designing and presenting components of the digital library to enhance learning.

Information Literacy: A Conceptual Framework for "Learning and the Digital Library"

In her thorough and useful overview of the development and current status of "information literacy," Behrens (1994) cites a number of definitions that have been proposed for this umbrella term. The definition included in the American Library Association's 1989 *Presidential Committee on Information Literacy: Final Report*—which she quotes as "the most frequently used today" (p. 315)—is striking in its interweaving of many of the concepts related to information studies and learning with media that have been discussed earlier:

> To be information literate, a person must be able to recognize when information is needed and have the ability to locate, evaluate, and use effectively the needed information. . . . Ultimately, information literate people are those who have learned how to learn. They know how to learn because they know how knowledge is organized, how to find information, and how to use information in such a way that others can learn from them. They are people prepared for lifelong learning because they can always find the information needed for any task or decision at hand. (*ALA Presidential Committee Report*, p. 1, quoted in Behrens, 1994, p. 315)

This definition makes explicit the link between information use and learning: it specifies the higher-order thinking skills associated with effective information use, states the importance to information literacy of know-

ing "how knowledge is organized," and stipulates that preparation "for lifelong learning" is the primary goal of information literacy. Its integration of concepts inherent to learning with those essential to information use suggests a theoretical structure that not only encompasses ideas from both information studies and instructional technology but anchors the two fields within a larger framework—a framework that provides useful guidance for considering the digital library as a learning environment.

Tools and procedures related to this "information literacy" framework have existed within the school library media community for years, and many can be mined for suggestions to support children's learning within the digital library. For example, Eisenberg and Berkowitz's (1990) "Big Six Skills" approach to library and information-skills instruction, Kuhlthau's (1993) work on how users seek meaning, and Stripling and Pitts's (1988) insights on teaching library research as a thinking process can be readily adapted to the electronic environment. A variety of work on resource-based teaching and learning can also provide direction for helping students become efficient and effective manipulators of EIRs. Neuman's (1995b) Delphi study suggests a number of specific "information literacy" concepts that students must master in order to use these resources in the service of higher-level learning: for example, "Understanding the general nature of searching" and "Understanding criteria for judging the value of particular citations" garnered perfect means of 4.0 from the study's panel of experts, while such other abilities as "Understanding the general nature of research," "Designing effective search strategies," "Identifying researchable topics," and "Generating search terms" all received mean ratings of over 3.9.

The series of standards for information literacy proposed by various states (for example, California Media and Library Educators Association, 1994; Colorado Department of Education, State Library and Adult Education Office, 1994) also provide broad conceptual guidance for addressing learning as well as information use within the digital library. Building on these ideas, the new national guidelines and standards for school library media programs to be published in 1998 by the American Association of School Librarians and the Association for Educational Communications and Technology will provide an even clearer statement of the relationship between information use and student learning. Not only will that document stipulate "information literacy standards for student learning," it will identify the links between these standards and the content and process standards of the full range of K-12 subject matter areas (Marcoux & Neuman, 1996). By specifying learning outcomes for information literacy and delineating the relationships of these outcomes to outcomes in such core subjects as English, history, mathematics, and so on, this document will provide a powerful tool to assist library media specialists in fostering higher-level student learning through the use of

information resources related to topics across the curriculum. The document will also provide a framework for further research into the ways in which the various components of the digital library, individually and in the aggregate, might be marshaled to promote that learning.

Conclusion

"Learning and the digital library" has two distinct components: learning related to accessing, evaluating, and using the information resources available in this environment and learning related to mastering and building upon the ideas embodied within those individual resources. Research, theory, and practice from information studies provide guidelines for fostering the first kind of learning, while research, theory, and practice from instructional technology provide insights about the second. Concepts and guidelines from information literacy provide a framework for helping students, library media specialists, and researchers understand and address a variety of issues related to learning in this rich and exciting new environment.

These areas suggest three promising avenues for fostering higher-level learning within the digital library. Research from a variety of other fields—for example, reading comprehension, interface design, and problem solving—should also be investigated for the insights they can bring to enhancing the learning potential of the digital library. To help students achieve the maximum learning benefits afforded by the unmatched number and connectivity of the resources of this exciting environment, educators and system designers alike must draw from all these traditions. Optimizing the learning potential of the digital library for the children in our schools will require the best thinking from all the disciplines that contribute to our understanding of how children learn. The challenges as well as the opportunities, like the digital library itself, are virtually unlimited and only beginning to be explored.

References

Aversa, E., & Mancall, J. C. (1986). Managing online information services in school library media programs. In S. L. Aaron & P. R. Scales (Eds.), *School library media annual 1986* (pp. 219-236). Littleton, CO: Libraries Unlimited.

Behrens, S. J. (1994). A conceptual analysis and historical overview of information literacy. *College & Research Libraries, 55*(4), 309-322.

California Media and Library Educators Association. (1994). *From library skills to information literacy: A handbook for the 21st century.* Castle Rock, CO: Hi Willow Research & Publishing.

Callison, D., & Daniels, A. (1988). Introducing end-user software for enhancing student online searching. *School Library Media Quarterly, 16*(3), 173-181.

Clark, R. C. (1983). Reconsidering research on learning from media. *Review of Educational Research, 53,* 445-460.

Colorado Department of Education, State Library and Adult Education Office, and Colorado Educational Media Association. (1994). *Model information literacy guidelines.* Denver, CO: Colorado Educational Media Association.

Crane, B., & Markowitz, N. L. (1994). A model for teaching critical thinking through online searching. *Reference Librarian, 44,* 41-52.

Eisenberg, M. B., & Berkowitz, R. E. (1990). *Information problem solving: The Big Six Skills approach to library and information skills instruction.* Norwood, NJ: Ablex.

Fleming, M., & Levie, W. H. (1978). *Instructional message design: Principles from the behavioral sciences.* Englewood Cliffs, NJ: Educational Technology Publications.

Fleming, M., & Levie, W. H. (Eds.). (1993). *Instructional message design: Principles from the behavioral and cognitive sciences* (2d ed.). Englewood Cliffs, NJ: Educational Technology Publications.

Gagne, R. M. (1977). *The conditions of learning* (3d ed.). New York: Holt, Rinehart & Winston.

Goodrum, D. A.; Dorsey, T.; & Schwen, T. M. (1993). Defining and building an enriched learning and information environment. *Educational Technology, 33*(11), 10-20.

Hannafin, M. J. (1992). Emerging technologies, ISD, and learning environments: Critical perspectives. *Educational Technology Research & Development, 40*(1), 49-63.

Hannafin, M. J.; Hall, C.; Land, S.; & Hill, J. (1994). Learning in open-ended environments: Assumptions, methods, and implications. *Educational Technology, 34*(10), 48-55.

Kozma, R. B. (1994). The influence of media on learning: The debate continues. *School Library Media Quarterly, 22*(4), 233-240.

Kozma, R. B. (1991). Learning with media. *Review of Educational Research, 61,* 179-211.

Kuhlthau, C. C. (1993). *Seeking meaning: A process approach to library and information services.* Norwood, NJ: Ablex.

Large, A.; Beheshti, J.; Breuleux, A.; & Renaud, A. (1994a). A comparison of information retrieval from print and CD-ROM versions of an encyclopedia by elementary school students. *Information Processing & Management, 30*(4), 499-513.

Large, A.; Beheshti, J.; Breuleux, A.; & Renaud, A. (1994b). Multimedia and comprehension: A cognitive study. *Journal of the American Society for Information Science, 45*(7), 515-528.

Lathrop, A. (1989). Online information retrieval as a research tool in secondary school libraries. In A. Lathrop (Ed.), *Online and CD-ROM databases in schools: Readings* (pp. 287-339). Englewood, CO: Libraries Unlimited.

Liebscher, P., & Marchionini, G. (1988). Browse and analytical search strategies in a full-text CD-ROM encyclopedia. *School Library Media Quarterly, 16*(4), 223-233.

Mancall, J. C. (1984). Training students to search online: Rationale, process, and implications. *Drexel Library Quarterly, 20,* 64-84.

Marchionini, G. (1989). Information-seeking strategies of novices using a full-text electronic encyclopedia. *Journal of the American Society for Information Science, 40*(1), 54-66.

Marchionini, G., & Teague, J. (1987). Elementary students' use of electronic information services: An exploratory study. *Journal of Research on Computing in Education, 20,* 139-155.

Marcoux, B., & Neuman, D. (1996). Into the twenty-first century: New guidelines and standards for library media programs. *School Library Media Quarterly, 24*(4), 213-218.

Neuman, D. (1993). Designing databases as tools for higher-level learning: Insights from instructional systems design. *Educational Technology Research and Development, 41*(4), 25-46.

Neuman, D. (1995a). *High school students' use of databases: Competing conceptual structures.* Unpublished paper presented at the Annual Meeting of the American Society for Information Science, October 1995, Chicago.

Neuman, D. (1995b). High school students' use of databases: Results of a national Delphi study. *Journal of the American Society for Information Science, 46*(4), 284-298.

Park, I., & Hannafin, M. J. (1993). Empirically based guidelines for the design of interactive multimedia. *Educational Technology Research and Development, 41*(3), 63-85.

Perkins, D. N. (1991). What constructivism demands of the learner. *Educational Technology, 31*(9), 19-21.

Perzylo, L., & Oliver, R. (1992). An investigation of children's use of a multimedia CD-ROM product for information retrieval. *Microcomputers for Information Management, 9*(4), 225-239.

Rieber, L. P. (1990). Using computer animated graphics in science instruction with children. *Journal of Educational Psychology, 82,* 135-140.

Rieber, L. P. (1996). Computer-based microworlds: A bridge between constructivism and direct instruction. *Educational Technology Research & Development, 40*(1), 93-106.

Scardamalia, M.; Bereiter, C.; McLean, R.; Swallow, J.; & Woodruff, E. (1989). Computer-supported intentional learning environments. *Journal of Educational Computing Research, 5*, 51-68.

Scardamalia, M.; Bereiter, C.; Brett, C.; Burtis, P. J.; Calhoun, C.; & Smith, L. N. (1992). Educational applications of a networked communal database. *Interactive Learning Environments, 2*(1), 45-71.

Small, R. V., & Ferreira, S. M. (1994). Multimedia technology and the changing nature of research in the school library. *Reference Librarian, 44*, 95-106.

Solomon, P. (1993). Children's information retrieval behavior: A case analysis of an OPAC. *Journal of the American Society for Information Science, 44*(5), 245-263.

Solomon, P. (1994). Children, technology, and instruction: A case study of elementary school children using an online public access catalog (OPAC). *School Library Media Quarterly, 23*(1), 43-53.

Stripling, B., & Pitts, J. M. (1988). *Brainstorms and blueprints: Teaching library research as a thinking process.* Englewood, CO: Libraries Unlimited.

Wozny, L. A. (1982). Online bibliographic searching and student use of information: An innovative teaching approach. *School Library Media Quarterly, 11*(1), 35-42.