Information Technology Literacy: Task Knowledge and Mental Models

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ABSTRACT

THIS ARTICLE DESCRIBES THE IMPORTANCE OF information technology literacy as a precursor to information literacy. It discusses the differences between the two literacies and makes comparisons and contrasts. It suggests a methodology for identifying task knowledge that might be used to build an information technology literacy program or curriculum. It examines how mental models can be used to facilitate acquisition of task knowledge and thus plays an important role in developing an information technology literacy.

INTRODUCTION

To be "information literate" in networked environments, users must be "technology literate" as well. There are few places where information retrieval—a primary element of information literacy—does not involve sophisticated information technology. Understanding how to use the technology must be a prerequisite to proficiency in finding, using, and evaluating information successfully. This understanding should be "conceptual," not simply functional. Just as information-seeking skills alone are not adequate outcomes for information literacy, technology skills alone are not adequate outcomes for information technology literacy. A broader perspective must be embraced.

INFORMATION LITERACY

The need for information literacy has been well documented in the literature of library and information science, and a definition is well es-

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tablished (Dupuis, 1997). It has been argued for some time that information literacy goes beyond the skills and knowledge involved in information seeking and retrieval, and strives for higher levels of understanding regarding the context of information in today's society, its composition and organization, as well as its use in lifelong learning. In its 1989 Final Report of the Presidential Committee on Information Literacy, the American Library Association (ALA) (1989) emphasized the importance of understanding how information is generated, organized, and used to the degree that an information literate person could teach others.

Dating back to times before the proliferation of computers and the Web, librarians often taught bibliographic instruction lectures and courses on how to use the library for research (Pask, et al., 1993). By 1990, as information became more and more digital and remotely available, some questioned the effectiveness of limited programs and called for a wider set of approaches than "how-to" lectures. Many institutions now embrace information literacy as a necessary component of the general studies portion of curricula in the Information Age (Loveless, 1998). With information systems becoming more and more complicated, it is possible that, at the college level, a technology literacy course would be a prerequisite for information literacy, if not other courses that require use of the Internet and the Web.

ALA's 1989 report was released a few years before the World Wide Web exploded on the scene. Since then, others have argued that not only are skills and knowledge of information itself important, but so are skills and knowledge of the technology that is often heavily integrated with the information. The Association of College & Research Libraries' (ACRL) (2000) Information Literacy Competency Standards for Higher Education notes: "Information technology skills enable an individual to use computers, software applications, databases, and other technologies to achieve a wide variety of academic, work-related and personal goals."

The ACRL Standards distinguish information literacy from information technology by noting that the literacy "is an intellectual framework for understanding, finding, evaluating and using information," focusing on information, not "on technology itself." Similarly, the National Research Council (NRC) (1999) distinguishes between basic technology literacy ("minimal level of familiarity with technological tools like word processors, e-mail, and Web browsers") and fluency ("persons understand information technology broadly enough to be able to apply it productively at work and in their everyday lives, to recognize when information technology would assist or impede the achievement of a goal"). The two definitions are not that far apart and yet are used differently. The NRC uses the term "literacy" to describe basic competency, whereas ACRL uses the term to describe a much more sophisticated understanding.

Information Technology Literacy

Information technology literacy is described here as a precursor to information literacy. The proper context is that an information technology literacy curriculum feeds directly into an information literacy curriculum. It has a different focus and aim than one that NRC describes as feeding into a management information systems or computer technology curriculum. As a precursor, students achieve skills and knowledge in information technology that allow them to enter an information literacy program at the appropriate and required learning level. It is not enough that students have rudimentary skills in using a given technology—instruction could be given one day in how to use a system, but the interface or underlying technology could change overnight.

Attention has not been given in the past to what a learner should bring to an information literacy program. Because technology is ever changing, competence is illusive—information systems change, software interfaces are upgraded or replaced, new technologies are invented and introduced. To anticipate and problem solve in such a constantly evolving environment, there is a need for a level of knowledge beyond simple competence (Brandt, 1997). Broader conceptual understanding about information technology should be a focus of a program that addresses information literacy while it takes into account information technology literacy. Turkle (1997) notes that students' motor and cognitive skills using computers allow them to quickly move through learning scenarios the way they move through computer games—by guessing, using trial and error, or simply finding the fastest way to the end result—and that this simulates learning, but does not foster it or facilitate knowledge acquisition.

Since computerized and networked information resources are an integral part of information seeking, there is a knowledge area which must be dealt with—some expertise in using the technology. Learners must have an understanding of the technological environment in which information resources are set, integrated, and used. Simple skills are not enough. Without some conceptual understanding, it is likely they will not attain a level of comfort and familiarity that can lead to expertise. Frustration with, and confusion about, information technology can impede access to acquiring knowledge in information literacy. For instance, without an understanding of how relevancy ranking works, naïve users of Internet search engines are likely to accept the claim that "best responses are shown first." Or, given "404 errors" in their results, they may assume there is nothing to match their request and fail to see the need for improving search heuristics to generate more results. In this way, the technology can interfere not only with the user's needs but the mission of information literacy.

A variety of difficulties with using information technology play havoc with information seeking and gathering. The blame for interference can be put on the Internet and correctly lies with the unreliable and changing nature of its technology. The underlying protocols that allow platform diversity contribute to a number of user problems. Much of the technology is still fairly new, and some is basically "shareware." Programs are often written by individuals as a hobby and are then offered to others. These, and more established software, are continually adapted to meet new demands. New software, or changes in older versions, continually present new situations to users. And since there is no single way to use the Internet, users constantly find themselves facing unfamiliar situations and all-too-familiar error messages. Internet technology is not sophisticated enough to adequately inform users about what has gone wrong (or what they should do next) when errors are encountered.

Little has been said in the literature about how to identify and integrate the use of technical skills as a component of information seeking. In the past, criticism has stemmed from the lack of effort in determining and utilizing measurable learning outcomes (Eadie, 1992). Even less effort seems to have been directed toward identifying or measuring prerequisite skills for a curriculum. It has been assumed that only rudimentary technical ability, minimal critical thinking skills, and minor problem solving are needed to undertake the learning in the information literacy curriculum. Until recently, few have adopted the use of a structured approach to developing a literacy curriculum to ensure that proper attention is paid to systematic needs. Some have noted that systematic attention can be focused on developing overall objectives using instructional systems design (Nahl-Jakobivits, 1992). Others have shown that such design can be used to match outcomes to instructional strategies for learning (DeWald et al., 2000). But a formal approach should also ensure that prerequisites for the learner are identified, analyzed, and accounted for in the instruction.

Instructional Systems Design

A generalized model of instructional systems design (ISD) requires at least five processes: (1) analysis, (2) design, (3) development, (4) implementation, and (5) evaluation (ASTD, 2000). Complex models of ISD, such as that of Dick and Carey (1993), break down the approach even farther into ten or more steps. The important piece for many designers is to end up with a result that includes attainable objectives and measurable outcomes. Often given less focus are those prerequisite skills or entry-level behaviors required to undertake the objectives and thus achieve the outcomes. A quick review of systems design shows where and how to include these in the overall process. (Note: in the discussion below, the term "instruction" is used to describe any aspect—training, instruction, or teaching—involved in the curriculum.)

Analysis can be performed in several areas. Gap analysis identifies a problem area by looking at skills and performance at the current level, projecting where they should be, and determining what is needed to move to the optimal condition or level. Learner analysis identifies characteristics of those who will participate in, and benefit from, the instruction. This can include demographic information, learning styles or preferences, prior skills and experiences, and attitudes or beliefs. Analysis of the environment looks at the setting and context of the learning—conditions related to where the learners will learn or apply the learning, social factors (peer pressures, work ethic, and so on), and the tools they will use. Analysis is the phase in which data and information is gathered, elements are compared and contrasted, and alternatives and options are explored.

The design phase takes trends and ideas generated from analysis and uses them to design a program or system. This is similar to drawing a blueprint, where a designer strives to take all the information into account concerning the learner, situation, and other elements identified in the analysis. This is the phase in which the vision, direction, and outcomes are pulled together to create an abstract plan that is often represented in a workflow diagram or storyboard. Design is fluid and abstract, as opposed to development, which is structured and concrete. The audience and expectations for a learning activity for a particular skill might be identified and ideas generated explaining how to achieve success, but the exact how and where it is carried out would be relegated to the development phase. For instance, based on students' use and requirements of their courses, it may be determined that it is important to teach how to use both search engines and indexes. However, which ones or how would be determined in the development phase.

With all the design elements laid out, the development phase involves choosing and building component parts such as the instructional materials, activities, tests, and so on. Foremost is the development of the objectives needed to meet outcomes and then matching components to the objectives. Within each objective, the steps needed to fulfill that objective are identified and listed. A starting point is determined for the steps. The prerequisites, or entry-level behaviors, needed to begin are also identified and listed. Figure1 indicates the process for determining prerequisite needs.

An example is an objective such as, "When searching for a current in-depth information source, freshman students will be able to identify the library's indexes Web site and find a category which matches their topic to identify indexes that will lead to retrieval of a pertinent article." Steps involved in this process might include: (1) enter a URL in a Web browser, (2) retrieve a library's site and click on the "indexes" link, (3) browse categories to find an index that relates to your topic, and (4) match categories to topic.

A crucial step often overlooked in development is the identification of the behaviors or skills that are a prerequisite for undertaking the task involved in this objective. In this case, skills could be differentiated as

Objective	
Describe objective for learning outcome indicating the behavior expected, the degree to which it must be mastered, and the conditions under which it is accomplished	Student will be able to move to a higher level directory [behavior] when presented with a URL [condition] to identify the homepage for a site when one exists [degree]
Steps to accomplish objective	
List all steps necessary to move through a sequence of actions to achieve the outcome listed under the objective	1. Click inside of Location box 2. Use backspace key to delete parts of the URL (from right to left) 3. Stop after a slash and load page
Prerequisites	
Identify entry level behaviors which the learner has to know in order to begin the first steps	- Can use a mouse to click inside a text box - Can backspace and reload a Web page - Can define URL, directory, slash

Figure 1. Establishing Prerequisite Behaviors.

information-seeking skills (identifying topic and generating synonyms) and technology skills. For instance, information-seeking prerequisites might include generating broad or narrow terms, whereas technology skills required prior to starting include: (1) maneuvering a mouse to enter text and click on links, (2) typing URLs in a Web browser and retrieving Web pages from other servers, and (3) scrolling up and down pages and selecting items from drop-down menus.

The importance of identifying prerequisite skills or entry-level behaviors is two-fold. First, it forces the designer to consider where instruction begins for a given module. It also causes the instructor to think about how prerequisite abilities should be assessed. Second, it allows learners to identify where the instruction begins so that they have an idea of the starting point. This allows them to self-assess their placement within the instruction. While there are several ways to assess entry-level behaviors, the most common one seems to be self-assessment by students. However, there is always the concern that students will self-assess themselves higher (or sometimes lower) than their actual abilities. For instance, when asked if they can evaluate Web pages, students often report in the affirmative, yet when asked what criteria they would use to do so, they are sometimes unable to list substantial elements.

Task Knowledge

Identifying the tasks and skills associated with information technology literacy is important. There are a variety of technology competence checklists and standards used in the workforce (DeBourcy, 1989). However, industry lists are usually set in a context that is performance-related (on-the-job requirements) for a specific industry or driven by a specific curriculum (education course-related outcomes that build on each other for mastery). One could use these as a starting point to identify outcomes on which to build an information technology literacy but, because the context is not an information setting, they might have little transfer or applicability.

A systematic way to identify pertinent tasks and outcomes in an information-seeking setting is to analyze the elements required to perform tasks, noting steps, sequence, requirements, and results when not performed correctly. For instance, in order to choose between two file formats for a document—HTML and pdf—users must be able to open files with the appropriate program. A requirement is that programs that open the files are available, and the user can indeed use them. The steps vary based on the program and how well it is integrated into the system at hand. But there is something additional that will help users to be successful in accomplishing their goals: knowing the difference between the formats, which comes with experience. Likewise, it helps to know the advantages or disadvantages of manipulating information with either of them. Experience helps to build a broader understanding of when and why to use a task, which is generally called task knowledge. The knowledge associated with a task allows a user to understand a context and establish relationships between a task and the setting in which it is placed. For instance, while anyone might be able to follow a recipe to bake a soufflé, task knowledge would influence the choice of baking utensil and oven or how well (and why) to beat the eggs based on prior experience and conceptual understanding.

Task knowledge is analyzed by observing novices performing a task and then watching experts perform the same task. The difference indicates the gap between beginner and advanced users but also gives insight into the lack or presence of task knowledge. One of the goals in identifying task knowledge is to describe the mental models of experts, specifically as it relates to using information technology. Figure 2 shows a conceptual representation of the relationship of tasks to task knowledge and mental models. If approaches can be described or shared with novices, it would help accelerate learning—when novices are shown expert ways, they can become experts faster.

As shown in Figure 3, experts and novices often have different approaches to problem solving based on their experiences and knowledge. Experience provides a set of problems from which comparison and contrast

Tasks (repeatable, concrete, usually sequential, skills)	Task Knowledge (conceptual understanding of steps as process and where/when to apply)	Mental Model (universal knowledge base which is a tool for problem solving)

Figure 2. Relationship of Tasks, Task Knowledge, and Mental Model.

Context for Task	
Having identified a possible link that may fill user's need, Web page takes over a minute to load.	
Novice Task	**Expert Task**
After waiting impatiently, novice hits the Back button and tries another link	After waiting to see if graphics are a problem, expert hits the Stop button and then forces the page to reload. Also considers changing options to stop graphics from loading.
Novice Task Knowledge	**Expert Task Knowledge**
A page that won't load is the result of a problem with the page or the server.	Graphics are bandwidth intensive. A slow page transmission is associated with current request—a subsequent transmission may not be slow and load normally.
Novice Mental Model	**Expert Mental Model**
Servers are like ATMs—when they are out of order user must go somewhere else.	Server interactions are similar to telephones, only the duration of a transmission is very short.

Figure 3. Analyzing Task Knowledge.

can help build a knowledge set. Such knowledge is compiled over time, which allows a person to reflect upon not only what works, but why or when certain approaches work better than others. As noted previously, knowledge associated with a task can then be applied to similar tasks or compared to different tasks in a way that allows breakthroughs in problem solving. With more experiences and breakthroughs, a person eventually develops a conceptual understanding of groups of tasks or applications in a larger context. Task knowledge can lead to conceptual understanding of the bigger picture. Well-developed conceptual understanding—for instance, how clients and servers interact—becomes a tool with which users can relate to or solve problems in other areas.

The goal of information technology literacy is to move from simply following steps to applying concepts when using technology. Conceptual understanding is solidified in a model that learners use to anticipate and solve problems in other situations and settings. Figure 2 indicates that task knowledge is enhanced when users have more conceptual understanding.

How does one teach for a conceptual understanding of technology? By focusing on the general idea of what it is that technology helps us do, instruction can begin to focus on concepts. This can be done by looking at the function a technology is supposed to fill, not just the end result of using it. For instance, if a learner looks at Windows as a way of organizing and accessing files by using menus and graphical representations, it becomes a little easier to explain the difference between Windows 3.1 and Windows NT. One can relate the menu and graphical nature of the two and then discuss the differences in using them. However, if a user sees Windows simply as the graphical way information is presented, he will have a hard time learning how to organize and manipulate files and folders. Another example is that, while making a bookmark or emptying the cache for a Web browser may be performed differently for Netscape than Internet Explorer, the concept behind the two is quite similar. A user could learn a recipe for saving a bookmark but not understand what a bookmark is or does. Once it is accepted that teaching for conceptual understanding can facilitate learning, attention can be turned to techniques for doing so.

Contemporary educational practice reveals a trend of borrowing from several disciplines to develop new approaches for dealing with technology. Criticism in the field of education has argued for some time that lecture-style methods of teaching are not effective. Current trends focus on learner-centered education where the emphasis is on the learner's perspective and how it helps them connect to the learning at hand (Resnick, 1989). More emphasis is being placed on activities such as hands-on labs, small group work, active participation, and exercises (Prorak et al., 1994). These approaches aim to engage learners by having them actively take part in the learning experience. Such approaches seem to be good at reinforcing both skills and concepts.

One approach, constructivism, goes a step further. It argues that learners are not passive vessels for receiving knowledge but are active participants who bring various tools to use into the learning process. In particular, they use mental models as the tools for constructing knowledge, and teaching should aim to build, strengthen, or alter those models (Tobin, 1993). The term "mental model" is borrowed from the cognitive science world, where it is defined basically as a system of outlooks or knowledge that a person uses to define the world in general or, specifically, a problem at hand (Seel, 1995). For example, a mental model of gravity allows one to determine that if an object floats it is either lighter than air (e.g., a helium balloon) or has some kind of propulsion that allows it to break away from gravity's pull (e.g., a helicopter).

Mental Models

Mental models are more than mere internal representations of external systems; these are complex schemas comprised of components and the relationships among them. It is argued that learners build and develop mental models over time as they interact with different systems (Gentner & Gentner, 1983). It is believed that people develop them through analogy by identifying and relating similarities and differences between known systems and facts and the new information or domain encountered (Greeno, 1983). Experts differ from novices in that they can use their mental models to produce strategies for dealing with problems that may be different from previous experiences on the surface level but that are conceptually similar.

A classic example of a mental model is revealed through the analogy that electricity is like water. Instructors can use students' basic understanding of water flowing through pipes to explain how electrons flow through wires (Gentner & Gentner, 1983). Another common example is that atoms are similar to solar systems. Other effective analogies include showing how gravity is similar to buoyancy or air pressure is like water pressure. In each of these examples, new knowledge is presented and related to other, already acquired, knowledge. However, mental models are more than just analogies. Students use their models as both knowledge base and toolbox for solving problems. The models allow them to make comparisons, understand exceptions, predict variations, and project scenarios to solve or avoid problems.

A student's mental model of an online catalog may be very limited. In high school, he or she may have been shown how to use the card catalog as a "look-up" tool which points to books. Classification in manual systems is usually limited to author, title, and subject. Thus, his or her mental model is of a very simple system analogous to a telephone book's white and yellow pages. When shown an online catalog, he or she will not understand the complexity and power of new generation systems. He or she have no model for understanding keyword searching, Boolean operators, or field limiting.

In fact, if students have used Internet search engines, their models for relating to online catalogs may be more like a slot machine or shopping at Amazon.com. They are probably used to typing in one word and taking their chances that something related to their need will rise to the top of the search results list. And if they cannot find something they want, just as they do with other shopping results, they may settle for what they find or even revise their needs to accommodate whatever is convenient and available.

Studies of mental models related to information seeking have supplied insight into how various groups understand and apply broader concepts and contextual knowledge related to information retrieval. One study found that a sophisticated searching system did not substitute for mental models of naïve users—the more complete the conceptual understanding, the less system errors users confronted (Dimitroff, 1992). Another group of studies showed that students could use and strengthen their mental models to help information seeking and lifelong learning when the focus was on process, not product (McGregor, 1994). Information literacy seeks to alter, shape, or develop mental models.

Users often create their own mental models in order to understand technology. Students sometimes view the Internet as a maze of rooms, like an arcade game, rather than a series of devices connected like the drives of a workstation. A primary step to building effective teaching approaches—a key ingredient of a literacy program—is to assess or survey existing models used by a given population. Once these models have been analyzed, teaching methods can be developed that help learners to adjust, extend, and alter these models. Constructivism argues that learners must be provided with carefully designed experiences to adjust their mental models and to construct knowledge for themselves. Experiences present the learners with a variety of situations that force them to test and, if necessary, alter their mental models. These experiences should, like the teacher's conceptual model, be designed with the learner's current mental models in mind.

Hands-on problem-solving experiences will move the learner toward expertise but will take time. Sharing conceptual understanding will accelerate learning and shape mental models. Figure 3 indicates the difference between task knowledge and mental models—but simply describing that difference will not promote knowledge building. There must be a way to influence knowledge growth. Some experts point to the use of analogy to do so.

Analogy itself can be compared to a concise articulation of a mental model—it represents a concept and serves as a tool to foster comparison and contrast to further promote understanding. An example of an analogy might be that accessing Web pages is like making a phone call. It can quickly express the ideas behind packet switching and relate the problem of error messages resulting from calls that are interrupted, cannot be placed, or result in busy signals. Analogy works best when numerous comparisons and contrasts can be made.

Conclusion

The inability to understand information technology in various settings and applications impacts the information literacy learner on several levels. First and foremost, students may not be prepared to begin an information literacy course or program—without comfort and competence, information technology can be a barrier to learning. Second, with only cursory skills (following "recipes"), they can get frustrated, waste time, and end up with hastily produced results for their information needs. Third, they may be unable to discern between technology literacy and information literacy, mistakenly thinking that mastering a particular interface is all they need to do to achieve long-term success. Combining analysis, task knowledge, mental models, and analogy can be useful in developing a program.

Learner analysis is a valuable, but often overlooked, tool. Students must be surveyed to better understand their knowledge levels, mental models, and learning styles. Generalizations regarding learner mental models or task knowledge may be found elsewhere (McGregor, 1994), but it is most useful for instructors to be directly in touch with their learners. A variety of techniques could be used to do so, ranging from random individual samples to representative focus groups.

As a part of learner analysis, it would be most useful to observe learners trying to accomplish information retrieval on their own. Even if they are able to articulate their mental models, insight into their approaches and techniques is best gained through empirical observation. By watching a variety of participants in the act of trying to search, for instance, one can get an idea of how they apply their mental models. By understanding task knowledge, instructors see firsthand the techniques and tools students prefer to use.

Knowing how learners think and act, it is easier to develop ways to influence their mental models. For instance, if students are used to searching Napster for music files, their mental model may be similar to that of selecting files from a networked jukebox and include a strong belief in simple keyword/title/author search (string or left-anchor searches in some information science parlance) while accepting information without considering its validity (no check to determine if this is an authoritative version of a song). Introducing the concept of a search engine as an intelligent jukebox that does not filter for quality may be one way to attach to and alter their mental models. Using analogies to which they can relate not only gets their attention, it allows them to bridge from the known (their mental model) to the unknown—this is also known as the "proximal distance" in educational theory (Tobin & Pippin, 1993).

The need to pursue this is twofold: information technology literacy is not found currently in curriculums, and it is a precursor to information literacy. Obviously, library and information science programs promote this literacy, but these do not seem to be addressed at undergraduate levels. As noted, this is not the same as computer literacy, although some think it is under the same umbrella (NRC, 1999). Other than general computer skills requirements, little seems to be available in the way of approaches or facilitation of information technology literacy (see Figure 4).

Information Literacy Outcome
"Orientation level users can identify various types of information sources and realize that there are a variety of classification systems for organizing them."
Possible Prerequisite Information Technology Literacy Outcome
Users can describe how Internet search engine spiders index web pages
Information Literacy Outcome
"[Intermediate] users create strategies and conduct searches for information about a given topic."
Possible Prerequisite Information Technology Literacy Outcome
Users can describe the basic parts of a relevancy ranking algorithm
(The Information Literacy Outcomes shown here are from Purdue University Libraries: http://www.lib.purdue.edu/InstructionalServices/ilc_summ.html)

Figure 4. Information Literacy Outcomes integrated with Information Technology Literacy Outcomes.

Of course, there is no one formula for incorporating either information literacy into any setting, let alone an information technology literacy. Some institutions, such as Earlham College or the University of Wisconsin, have formal requirements, such as courses or modules, in which information literacy competencies can be promulgated. In other places, such as the University of Oregon and Indiana-Purdue University at Indianapolis (IUPUI), formal liaison programs exist in which librarians work closely with schools and departments to develop course-integrated projects and assignments that promote such literacy competencies. In still others, such as Purdue University, libraries have taken it upon themselves to build a program and then push to get it inserted into university courses. It is hoped that the two literacies can be integrated. If an integrated perspective toward information technology grows, perhaps it is this latter approach—a "grassroots" movement—which librarians need to take to meet the challenge of developing an information technology literacy.

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