Cognitive Strategies and Learning from the World Wide Web

☐ Janette R. Hill
Michael J. Hannafin

The purpose of this study was to identify the strategies used by adult learners in an open-ended hypermedia information system. Four participants were drawn from an introductory educational technology course that incorporated a unit on telecommunications. Participants completed a survey measuring reported knowledge in three domains (metacognitive, system, and subject) as well as self-efficacy toward technology. They then identified a personal search topic, and searched the World Wide Web for information using Netscape®, thinking aloud as they searched. Data collection and analysis occurred in several phases: scripting the search, reading through the data, segmenting according to research question, encoding, and aggregating. Three major findings related to hypermedia information systems resulted from this study: (a) a variety of strategies are used by learners; (b) self-reported knowledge appears to affect the strategies used; and (c) perceptions of disorientation and perceived self-efficacy influence the strategies used. Implications related to emerging information technologies and open-ended learning environments are considered.

☐ During the past decade, information systems have undergone a metamorphosis. Emerging hypermedia information systems, such as the World Wide Web (WWW), have engendered a myriad of applications. While such systems promote *access* to a wide-reaching range of resources, they do not, by design, facilitate *learning*. The purpose of this study was to identify the strategies used by adults seeking to address individually defined learning needs via the World Wide Web.

PERSPECTIVES ON EMERGING INFORMATION SYSTEMS

Historically, information systems directed users to, and guided in retrieval of, limited text-based resources. Electronic card catalogs, for example, indexed a host of library resources such as abstracts and citations. Original source materials were rarely available; instead, users were informed where source documents were located (Marchionini, 1995).

Some have suggested that emerging hypermedia information systems such as the WWW signal a new era in both information system organization and in how education is conceptualized and delivered (Dede, 1996; Gilbert, 1996). The Web has expanded information systems to include on-line access to a theoretically unlimited number and type of multimedia documents, dynamic indexing among documents, and powerful search engines that assist users in identifying relevant documents (Williams, 1995). According to proponents, learners can iteratively generate problems or needs, develop and refine search strategies, locate related docu-

ments, compare and contrast perspectives, interpret the individual documents, generate new inferences and interpretations, and reconcile new with existing understanding (O'Neil, 1995; Spindler, 1995).

Concerns have been expressed, however, regarding learning applications of the WWW (see, e.g., Batson & Bass, 1996). Anyone can publish information on the Web on virtually any topic; consequently, little quality control of source documents exists. Likewise, Web search engines are designed to assist users in identifying and accessing source documents, not to assess the appropriateness of the documents for individual needs. Users are typically provided lists of Web resources with a system-assigned relevance rating, but the lists are generated via very general Boolean search algorithms which often prove misleading or of little use. Significant strides have been made in search engine technology, but search engines are thus far unable to locate information in a particular context for a particular use (Hildreth, 1987).

Research on information retrieval suggests problems in three key areas: (a) users, (b) systems, and (c) information (see Walster, 1996, for a detailed review). Systems and users are unable to establish a natural language dialog, resulting in communications breakdowns. Therefore, it is difficult to support unique learner goals, intentions, and understanding. Users are often unable to provide adequate search criteria; systems, in turn, return "hits" based upon limited search engine intelligence and source data inadequacies. As a result, inaccurate and misleading sources are identified by information systems as "relevant" which ultimately complicate or confound learning.

Still, the educational potential of the WWW for enabling the creation of open-ended learning environments (OELEs) has generated considerable interest. OELEs are learner-centered systems that facilitate the unique efforts of individuals versus transmitting uniform information to a class or group (Hannafin, Hall, Land, & Hill, 1994). OELEs are designed to facilitate problem solving, critical thinking, and perspective building as learners engage resource-rich environments (Land & Hannafin, 1996). The extent to which the WWW supports open-ended learning depends upon the extent to which relevant pedagogy is embedded within a given Web site, or scaffolding is provided (Hannafin, Hill, & Land, 1997). The WWW has significant potential; the extent to which the Web or individual sites support open-ended learning, however, depends upon their design and/or context of their application.

FACTORS INFLUENCING OPEN-ENDED LEARNING VIA THE WWW

In planning the present study, we conducted an analysis of the literature on information systems, including instructional systems design, psychology, communication, computer science, and information science, to identify elements likely to influence user-centered, open-ended learning. The review revealed five key factors: (a) metacognitive knowledge, (b) perceived orientation, (c) perceived self-efficacy, (d) system knowledge, and (e) prior subject knowledge. These are summarized in Table 1 and introduced briefly in the following section. They are described in the context of the present study in the "Method" section.

Metacognitive knowledge refers to awareness of one's cognitive processes. These strategies include scanning, searching, questioning, chunking, generating hypotheses, and making decisions (Flavell, 1979; Kozma, 1988). Metacognitive knowledge enables an individual to reflect, evaluate, and direct cognitive activities effectively (Perkins, Simmons, & Tishman, 1990). The decision-making and management demands of open learning via the WWW can be especially significant (Jacobson, Maouri, Mishra, & Kolar, 1995; Yang, 1993). Metacognitive knowledge presumably influences how or if individuals identify and monitor their learning needs—skills considered fundamental to successful open learning (Hannafin et al., 1997). Weak metacognitive knowledge and skill may limit learners in defining learning needs, evaluating available resources, and revising their learning strategies, while strong metacognitive knowledge and skill are likely to improve learning via the information system.

Perceived orientation refers to awareness of

Table 1 ☐ Stages of knowing and understanding

Knowledge Area	*Beginning*	*End*
Metacognitive	Low—Learners trained to think in linear manner in directed environments with little to no control.	High—Display divergent thinking and views from multiple perspectives (angling).
Orientation	Low—Learners experience being "lost in hyperspace."	High—Learners are aware of where they are, how they got there, and how to get back to previous locations within the system.
Self-Efficacy	Low—Learners do not feel confident in their ability to use the system.	High—Learners are not only confident in using the system, but are also willing to try new things with the system.
System	Limited—Learners may have used a computer, but likely not to have used the particular system, especially in the manner in which it is being utilized.	Expanded—In addition to the manner in which the tool was designed, learners will also be utilizing the system in divergent ways.
Subject	Limited—Novice or basic understanding of the domain area.	Enhanced—Increase in understanding. Movement toward expertise in area.

location within a system, as well as awareness of the strategies and activities needed. The ability to recognize location, or gain "bearings" in a system, influences success in open systems (Beasley & Waugh, 1995). Disorientation, or feeling "lost in hyperspace," hampers learning because of the loss of bearings (Tripp & Roby, 1990). While some have found that modest disorientation may create a challenge for the learner (see, e.g., Mayes, Kibby, & Anderson, 1990), high-levels of disorientation have proven debilitating (Marchionini, 1988).

Perceived self-efficacy refers to a personal judgment of one's capability to execute actions required to perform. According to Bandura (1977), self-efficacy influences choice: "Given appropriate skills and adequate incentives, efficacy expectations are a major determinant of people's choice of activities, how much effort they will expend, and how long they will sustain effort in dealing with stressful situations" (Bandura, in Oliver & Shapiro, 1993, p. 194). Perceived self-efficacy toward emerging hypermedia information systems are likely to influence how, or if, participants use the system (Ashton, 1984; Hill, Smith, & Mann, 1987; Jorde-Bloom, 1988; Kinzie & Delcourt, 1991; Kinzie, Delcourt, & Powers, 1994). Low self-efficacy reflects a lack of confidence in the ability to manipulate the system to achieve desired results. Consequently, users are more likely to accept rather than question system-generated information. Users with high self-efficacy, in contrast, tend to be more persistent in their search and more confident in their ability to locate the resources they seek (Murphy, 1988).

System knowledge refers to prior knowledge of and experience with a particular information system or a system closely related in structure and function. High system knowledge enables strategic and sophisticated uses of search and retrieval features. Low system knowledge often reflects a lack of awareness of how approaches can be augmented, as well as how features might extend approaches and perceptions (for further discussion, see Marchionini, 1995). Weil, Rosen, and Wugalter (1990) concluded that, lacking prior system knowledge and experience, users experienced difficulty communicating with and through computers. The lack of an adequate mental model may also minimize the value of extensive domain knowledge during searches (Park & Hannafin, 1993). On the other hand, experienced users, such as reference librarians, generally evolve sophisticated techniques despite the lack of extensive domain knowledge (Marchionini, 1995), enabling them to maneuver through complex information systems to locate needed information.

Prior subject knowledge refers to existing knowledge and experience related to the domain in which one searches. According to Ausubel (1963), ". . . an individual's (existing) organization, stability, and clarity of knowledge

in a particular subject matter field at any given time, is the principal factor influencing the learning and retention of meaningful new material" (p. 217). Independent of medium, learners with extensive content-related prior knowledge consistently out-perform their counterparts with limited prior knowledge (Langer & Nicolich, 1981; Recht & Leslie, 1988). High domain knowledge enables learners to better anticipate, as well as to identify, connections among terminology than does limited domain knowledge, thus enabling learners to generate powerful strategies that are largely independent of specific information systems (Shin, Schallert, & Savenye, 1994). Information systems, in effect, extend inquiry via schema-driven searches in a familiar domain rather than assist in the acquisition of enabling conceptual knowledge or skill (Marchionini, 1995).

IMPLICATIONS FOR PRESENT STUDY

While considerable interest and effort has been focused on the design and structure of user-centered information systems (see, e.g., Kuhlthau, 1991), several questions remain related to the influence of varied background knowledge, metacognitive knowledge, perceived self-efficacy, and prior experience. We need to better understand the processes employed as learners search, as well as the search process itself, to improve the utility of systems such as the WWW for open learning. The goals of this study were to better understand how individual learning goals were pursued using the WWW, and to suggest methods to guide their design and use in open-learning environments. Because of the dynamic interactions inherent in open learning via the WWW, qualitative methods involving multiple data sources and diverse techniques were employed.

A primary organizing question was addressed: What strategies are employed by learners in open-ended hypermedia information systems? Five secondary questions framed the study:

1. Does metacognitive knowledge affect the strategies employed?
2. Does perceived orientation affect the strategies employed?
3. Does perceived self-efficacy affect the strategies employed?
4. Does prior system knowledge affect the strategies employed?
5. Does prior subject knowledge affect the strategies employed?

METHOD

Selection of Participants

Fifteen volunteers, comprising current and prospective educators enrolled in a university-level technology for educators course, initially participated. The participants reflected varied experiences and backgrounds, including preservice teachers, as well as current pre–K through postsecondary educators. Since the course was an elective, participants entered with high levels of interest in and motivation for applying technology in their work. They were awarded extra credit for participating.

Following data collection (i.e., Presearch Survey through Stimulated Postsearch Interview) from all study volunteers, the initial pool of participants was reduced to four, including two males and two females, for in-depth analysis. They were selected because of the diversity and richness of the data presented in the various instruments, and to minimize redundant information across participants. The purpose was not to generalize to a broader population, but to characterize both diversity and similarity of individual strategy use within a given context (Whitt, 1991). Selection ensured diversity across the attributes under study and provided the most complete information on the questionnaires, interviews, and study procedures. Participants are described in greater detail in the "Findings and Discussion" section.

The Course: Technology for Teachers

The course philosophy reflected several OELE premises:

- First, within educational settings, technologies are tools to be used to build or construct. The course focused on the creation of products that were keyed to identified needs.

- Second, productive use is influenced by context, audience, and activity. Course problems were anchored in everyday classroom teaching and learning contexts; various technologies could support student, teacher, and community uses. Open learning is student centered. Participants established and updated individual personally relevant goals to be pursued as well as the steps needed to attain them.
- Third, concrete, relevant contexts establish both everyday referents and the meaningfulness of learning activities. In this course, individuals identified specific problems, based on their work sites, to be addressed using the technologies and resources available in the course.
- Finally, the underlying *processes* associated with technology applications are critical for developing understanding because existing technologies will inevitably be replaced. Therefore, problem solving using available tools was stressed rather than mastery of specific software and hardware.

Internet and WWW

A major focus of the course was the WWW. Most participants were aware of the Web, though few understood what it was or how it could be used in an educational setting. The WWW supports the transmission of multimedia, such as pictures, sound, and motion, as well as traditional textual information. While not inherently an OELE, learning via the Web can be scaffolded using features such as learner-generated problems and tools that enable the user to choose, query, and link documents — conditions provided via the Technology for Teachers course.

The WWW and *Netscape*® have several characteristics that made them appropriate for the study. First, both the Web and *Netscape*® are common components of open information systems and are widely available in schools. Second, the WWW requires that the learner generate the strategies needed to plan, implement, and evaluate search results. *Netscape*® supports these activities, enabling access to millions of Web sites and Web pages, and readily enables access to several search engines to locate information (e.g., *Yahoo*®). Finally, control is user centered, in terms of the needs defined, information requested, and steps taken to retrieve information.

Measures

Both quantitative and qualitative instruments and techniques were used to gather self-reported knowledge: presearch surveys, think-aloud protocols, audit trails, postsearch questionnaires, and stimulated postsearch interviews. The instruments were used to designate participants as high, medium, or low in the five attributes studied and to corroborate participants' verbalizations during their search.

Presearch Survey

The presearch survey measured participants' initial perceptions in the three knowledge domains (metacognitive, subject, system) and their perceived self-efficacy. The survey established a baseline from which to evaluate perceived progress. Twenty-two questions were used to gather information related to the four areas. The questions included both short answer and rating questions.

Metacognitive knowledge was ascertained via a pizza-making exercise, during which participants identified steps to be taken in making a pizza, and responded to four short-answer questions such as, "Were you aware of monitoring what you were doing as you were making the pizza?" This was done to indicate participant awareness of their ongoing metacognitive processes during the exercise. Responses to these questions were used to indicate participants' initial perceptions of metacognitive knowledge.

Four questions on the presearch survey were related to participants' prior subject knowledge. Participants were asked to explain their search task (i.e., "The problem I am trying to solve is: . . .") and to rate their knowledge of the topic area in which they were searching for information. For example, participants rated themselves on a scale of *novice* to *expert* in response to the follow-

ing question: "How would you rate your knowledge of the topic area you will be searching?"

The presearch survey contained seven questions related to system knowledge. The questions were related to information retrieval systems in general (e.g., ERIC) and hypertext/hypermedia systems (e.g., *Netscape*®). Participants indicated their experience with information-retrieval technologies (from *never used* to *daily use*) in the following system knowledge stem: "Indicate the degree to which you have used the following technologies: General information retrieval databases (e.g., PsychLit, ERIC). These ratings were used to indicate the participants' perceived levels of system knowledge.

Seven questions on the survey were related to self-efficacy. For example, participants rated from *strongly disagree* to *strongly agree* the following self-efficacy stem: "I am not the type to do well with computer technologies." Responses on these questions were used to indicate the participants' levels of perceived self-efficacy.

Think-Aloud Protocols

Think-aloud protocols, verbalizations of en-route thought processes, were recorded on both audiotape and videotape. Participants were encouraged to verbalize what came to mind as they worked in the system. Once the verbalizations were recorded, transcriptions were created. Think-aloud protocols provided us with an external artifact of the thought processes in which participants engaged during their searches (Ericsson & Simon, 1984).

Audit Trails

Videotapes of the search sessions were used to generate audit trails of individual searches. Such audit trails have been used previously to trace hypermedia navigation paths (Gay & Mazur, 1993; Misanchuk & Schwier, 1991; Shin, et al., 1994). An audit trail is a visual representation of the path taken in a computer-based environment. In this study, the locations of "point and click" responses that activated hyperlinks or buttons were recorded as navigation points. In collaboration with think-aloud protocols, audit trails provided a record of actions and system responses associated with presumed cognitive processes.

Postsearch Questionnaires

Like the presearch survey, the postsearch questionnaire measured participant estimates of the three knowledge areas (metacognitive, subject, system) and perceived self-efficacy. In addition, the questionnaire queried participants for strategies used and perceived orientation during their searches. The postsearch questionnaire enabled the perceived changes from the start to completion of a search session to be studied. Seventeen short-response questions were included on the questionnaire. Though the majority of the questions were keyed to the five research areas (metacognitive knowledge: 2 questions; subject knowledge: 2 questions; system knowledge: 3 questions; perceived orientation: 2 questions; perceived self-efficacy: 3 questions), the questions were open-ended in nature, leading to responses that often overlapped across the research areas. For example, questions were posed related to system knowledge and system orientation: "Did you feel like you knew where to find the information you needed and how to get it?" and "Did you ever feel "lost" or confused as you were using *Netscape*®? When? What did you do to try and overcome this feeling?" Responses to the questions were used to indicate the participants' perceived levels of knowledge (metacognitive, subject, system), perceived orientation, and perceived self-efficacy.

Stimulated Postsearch Interviews

Following the transcription of protocols and the creation of audit trails, participants were interviewed individually to gather additional reflections and comments related to their search. Videotapes of the participant's search were used during the interview to stimulate recall. The interviews helped to establish perceived knowledge and success at individual tasks. As with the postsearch questionnaire, queries during the stimulated postsearch interview emphasized the five attributes examined in the study. For example, when asked to reflect on metacognitive

awareness, participants were asked: "Did your search strategy change over time? If yes, what made you change your strategy? If no, what indicated to you that your strategy was effective?"

Other interview questions were based on the initial analysis of each participant's search. Areas targeted for follow-up reflected instances when the participant expressed confusion or exhibited contradictory behavior. Contradictory behavior was defined as an action taken that did not appear related to the information provided by the system or in the participant's think-aloud statement. For example, some participants viewed information that offered a potential solution to the problem pursued in their search, yet they did not perceive it as relevant.

DESIGN AND ANALYSES

Embedded case study methods were employed, involving multiple cases as embedded units within a larger context. Each participant was analyzed as an individual unit (Yin, 1994). The methods combined descriptive and analytical approaches. The research was descriptive in that the goal was to describe evidence gathered, including the perspectives of the participants and the researchers. During analysis, information was then transformed iteratively through analytical induction (Bogdan & Biklen, 1992), a procedure used to help categorize large amounts of information from diverse sources. Initial definitions and explanations of search strategies and techniques were derived from previous information-seeking studies in information processing and interactive strategy research (see, e.g., McGregor, 1993). In order to identify themes and trends, definition and explanation codes were used to categorize the data collected. Initial codes were refined and expanded as needed during analysis of the study data.

Attributes Studied

Metacognitive Knowledge

Metacognitive knowledge referred to the participant's self-reported awareness of cognitive processes. Each participant rated his or her initial metacognitive knowledge on the prestudy survey, then again on the poststudy questionnaire.

Perceived Orientation

Perceived orientation referred to an individual's awareness of location within a system and of strategies and activities needed to access desired information. Perceived disorientation was established during the analysis of the think-aloud protocols (Suchman, 1987) and again during the postsearch questionnaires and interviews.

Perceived Self-Efficacy

Perceived self-efficacy referred to judgments of one's ability to organize and execute needed actions using particular knowledge or skill. In this study, participants rated perceived self-efficacy, both in terms of using computer technologies in general and to search for information using electronic information systems, on the presearch survey and postsearch questionnaire.

System Knowledge

System knowledge referred to self-reported knowledge about electronic information systems in general and *Netscape*® in particular. System knowledge was assessed using presearch surveys, think-aloud protocols, postsearch questionnaires, and interviews.

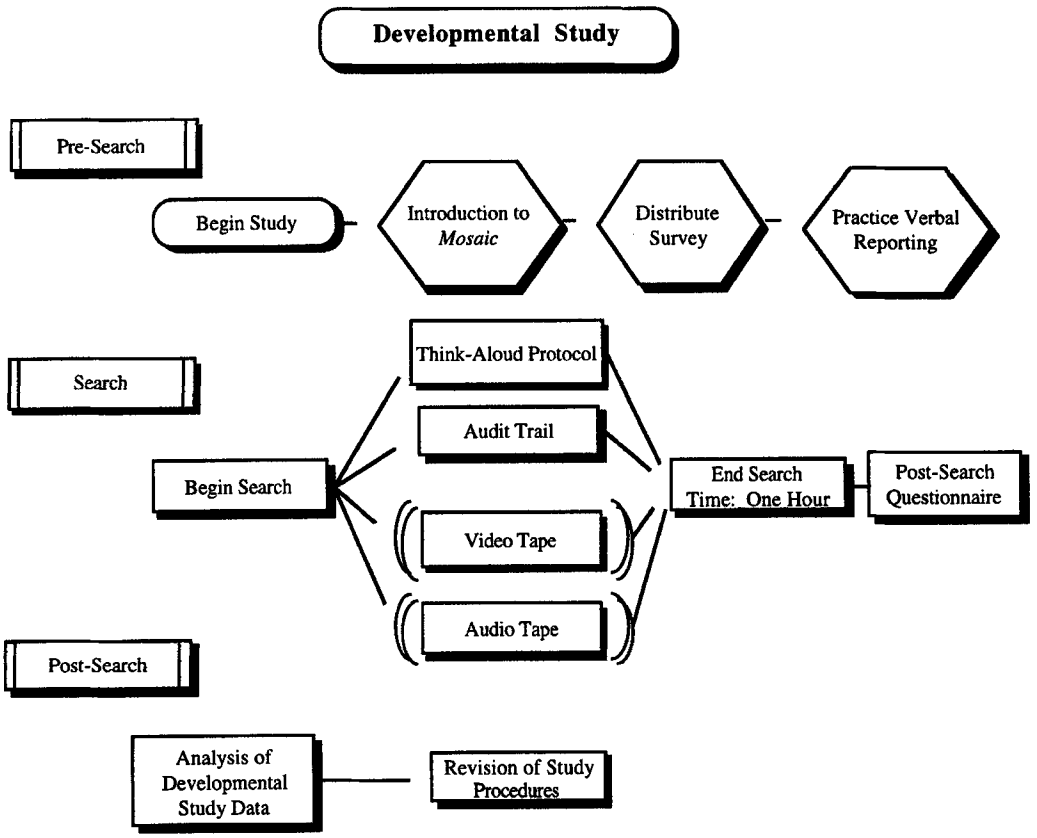
Prior Subject Knowledge

Prior subject knowledge referred to self-estimates of prior knowledge and experience related to the subject for which an individual search was conducted. Several instruments were used to gather data on prior subject knowledge: presearch surveys, think aloud protocols, postsearch questionnaires, and interviews.

Research Phases

Research activities, summarized in Figure 1, included three main phases: presearch activities, activities during the search, and postsearch activities. These components were implemented

Figure 1 ☐ Study activities



in two stages: developmental and formal. All research activities, including the developmental study, training, data collection and analysis, took place during a three-month period.

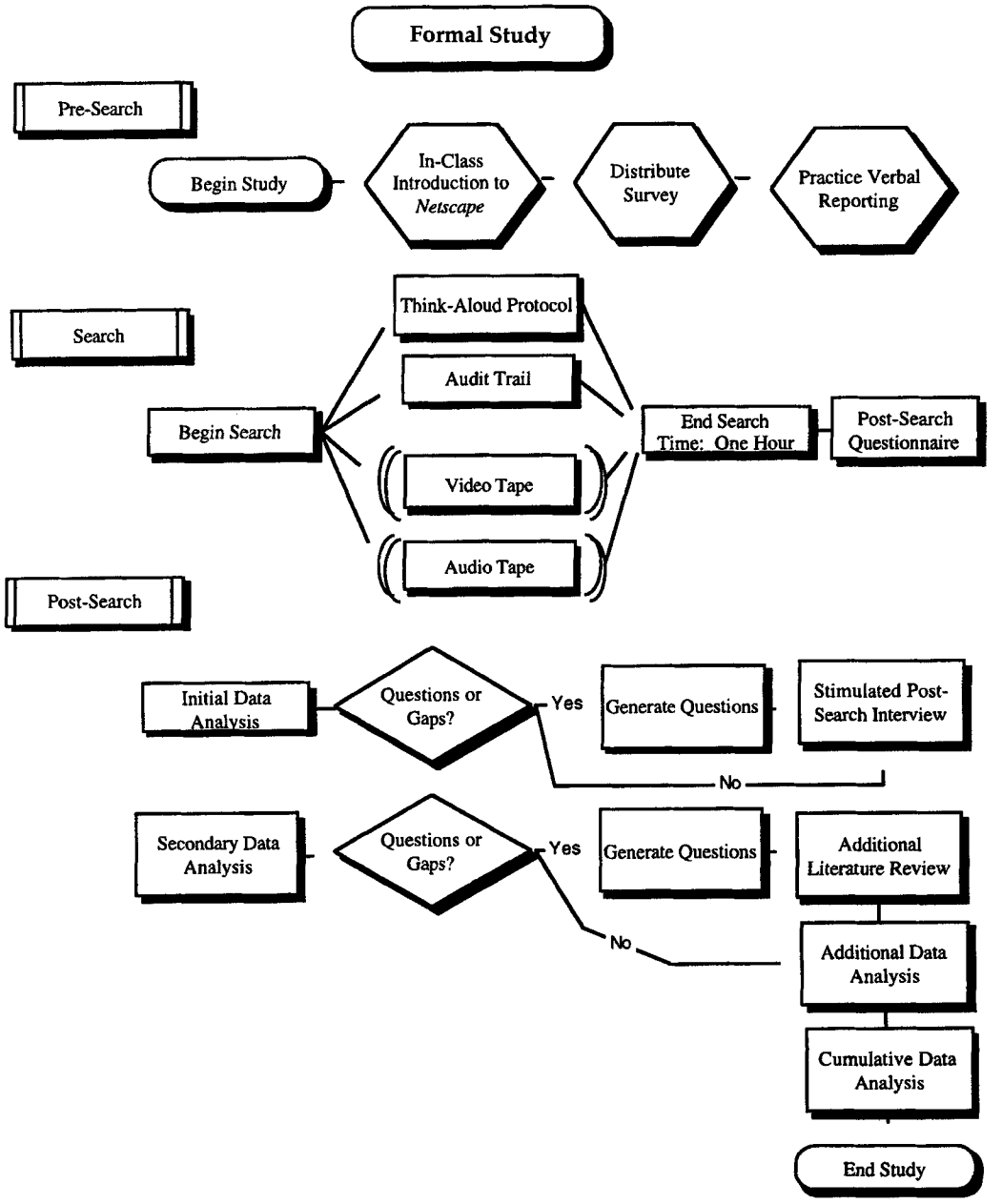
Developmental Study

The developmental study was undertaken initially to test the clarity of the questions and terminology, the dependability of the think-aloud procedures, and the feasibility of the technology in data gathering. Four students similar to those in the formal study participated. Each completed a survey measuring reported knowledge, the system used to complete the search task, and their metacognitive awareness. In addition, each rated perceived self-efficacy toward information searching, technology in general, and hypermedia information systems in particular.

Prior to the search, participants practiced verbal reporting. This activity involved counting aloud the number of windows in their house or apartment, a procedure designed to elicit spatial and mental visualizations by participants (see Ericsson & Simon, 1984). Following the practice session, participants searched using *Mosaic*®, a browser similar to *Netscape*®'s interface and function, thinking aloud as they searched. After searching, the participants completed a questionnaire.

Several research procedures, instruments, and techniques were validated, eliminated, or revised in the developmental phase of the study. The practice session for the think-aloud protocol proved sufficient to elicit verbalizations. Participants adapted readily to the task, and required few reminders to think-aloud. In addition, the survey and interview instruments and proce-

Figure 1 ☐ *(continued)*



dures were revised to ensure both clarity and ease of use. Data gathering techniques were also validated, including both the simultaneous searching and think-aloud methods among multiple participants. Finally, the postsearch questionnaire provided corroborating data for search verbalizations and enabled analysis of pre-to-post perceptions, while the stimulated postsearch interview generated feedback regarding the meaning of en-route verbalizations.

Several participants indicated insufficient preparation in the use of the system. Two adjustments were made to address this concern: the first author provided additional detail during

the presentation, and an optional verbal review prior to the actual searching. During the developmental study, *Mosaic®* was found to be slow, awkward, and limited in its search support tools. Therefore, *Netscape®* was adopted for the formal study because of its improved speed and efficiency, and the availability of search engines to traverse the Web. Finally, technical problems in the use of video to capture both user actions and screen data were identified and resolved prior to the formal study.

Formal Study

The formal study is also represented in Figure 1. As with the developmental study, three phases were involved: presearch, during the search, and postsearch.

Presearch Activities. A three-hour introduction, which included basic information about the WWW, *Netscape®*, and the tools available to support searches, was provided. Several home pages were introduced, including the *Welcome* home page for *Netscape®* and *NetSearch*, *Netscape®*'s access page to search engines. Participants were encouraged to "play with" the system during the class, were given the presearch survey, and told to submit the survey when they returned for their scheduled search sessions one week later.

Participants practiced the think-aloud procedures employed in the study prior to their formal search session. As in the developmental study, they were asked to describe their thoughts as they determined the number of windows in their house or apartment. As participants practiced thinking aloud, the first author monitored the sessions and encouraged them to speak audibly as they thought.

Search Activities. The search task was initiated following the WWW and *Netscape®* introduction. During this session, the first author prompted the think-aloud process with statements such as: "Don't forget to talk about what you are thinking" and "What are you thinking now?" Reminders were provided when the participant's voice became inaudible, she or he ceased to speak or had difficulty thinking aloud.

Each participant's search was guided by his or her response to the statement: "How can I [the teacher] research new information for my unit [course subject] next week?" The problem task was both directed and exploratory in nature; that is, while participants were directed to devise a solution using *Netscape®* to find their information, the problem topic selected and methods used to solve the problem varied from individual to individual.

After completing the think-aloud practice session, participants began their search. Based on time results from a developmental study, one hour was identified as the typical search time for novice WWW users. Therefore, they were allotted one hour to complete their task, but were told they could return later if needed. Prior to searching, participants answered three questions:

1. What information do you hope to find during the search?
2. Do you have a strategy in mind for how you will find what you are looking for?
3. What do you plan to do with the information once you find it?

This information was used as an indication of strategies prior to, and after, the search session.

All participants began their search at the same home page, *Welcome to Netscape®*. *NetSearch* provided several search engines for finding information on the WWW and also on Internet Gopher servers, file transfer protocol sites, and Telnet locations. As the participants searched, the first author monitored and assisted with hardware problems, avoiding guidance in search completion.

To facilitate the search, a simple job aid was provided at each search station to remind participants of their role:

- Why did you select that?
- Why are you interested in that topic?
- What was interesting about that topic?

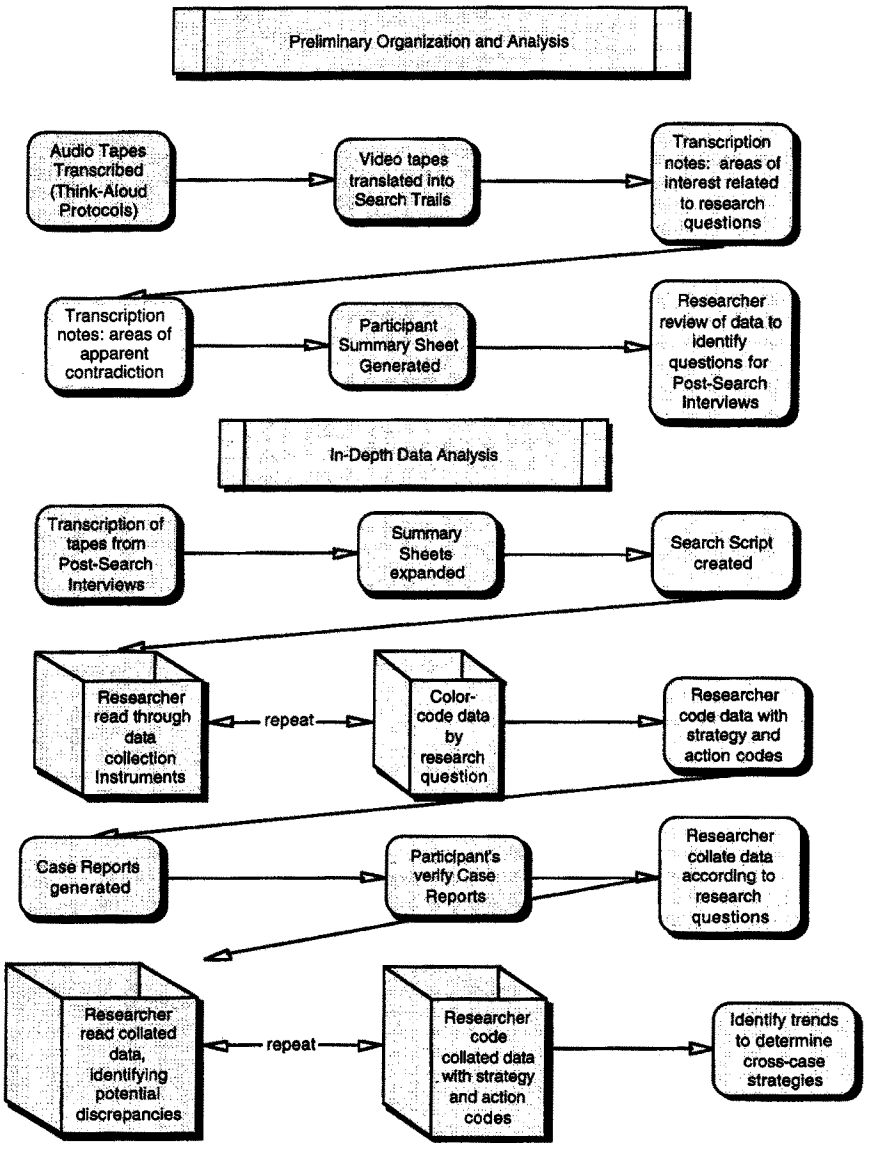
An overall think-aloud reminder,

- Don't forget to talk about what you are thinking,

was also included.

Postsearch Activities. After searching for one hour, participants were asked to complete the

Figure 2 ☐ Synopsis of analysis process



postsearch questionnaire. The questionnaire was completed and returned before they departed the lab. Participants also scheduled stimulated postsearch interviews to be completed during the following week.

Analysis and Procedures

As illustrated in Figure 2, data analysis was conducted during several phases. The relationships among the data, methods, and research questions are summarized in Table 2.

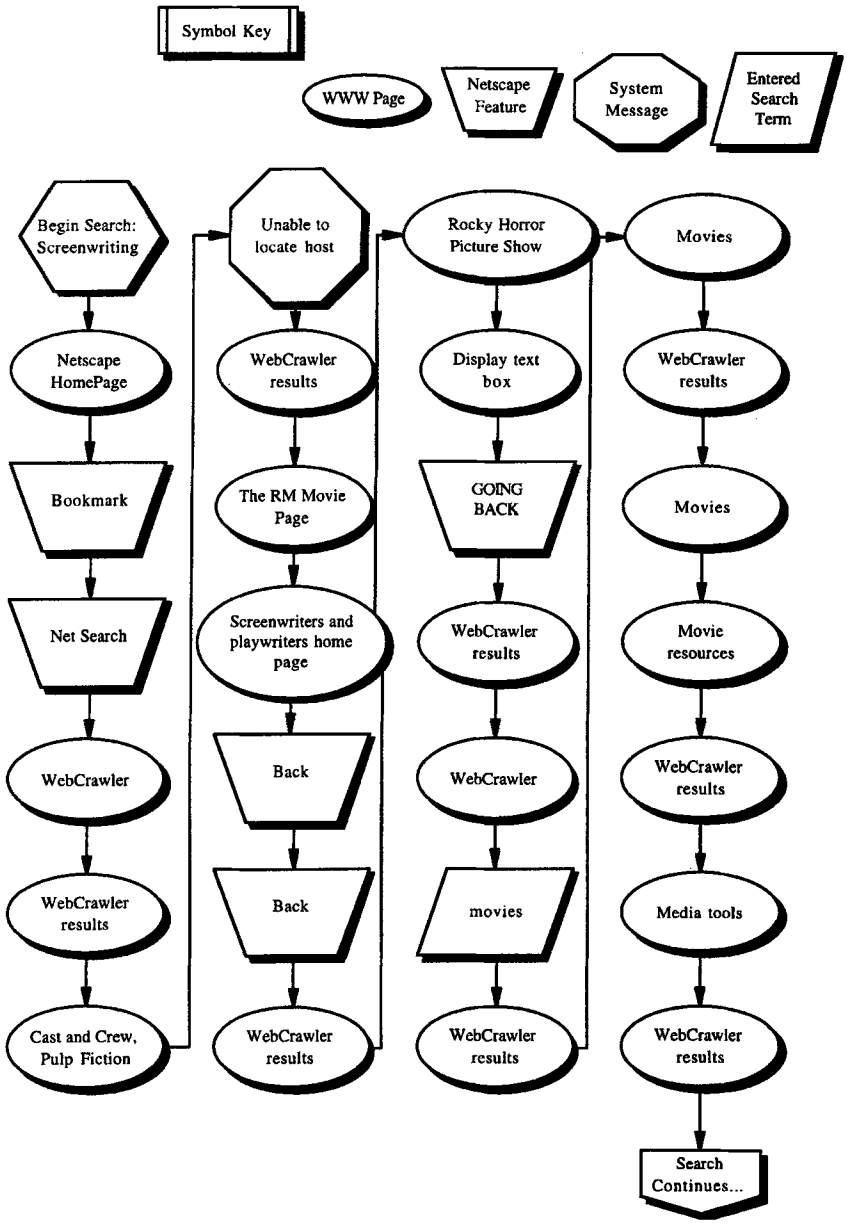
Preliminary Organization and Analysis

Most of the data collection, organization, and analysis occurred iteratively during a four-week period. This schedule helped to indicate gaps in data as they were gathered and organized, allowing adaptations and indicating the need

Table 2 ☐ Research question, data sources, and methods

Research Question	*Data Gathered*	*How Obtained*	*When*	*Who*
1. How does meta-cognitive knowledge affect the strategies employed?	Written responses to several questions	Presearch Survey	Presearch	Participant
	Protocol	Think-Aloud Protocol	Search	Participant
	Audit Trail	Video tape	Search	Participant
	Written responses to several questions	Postsearch Questions	Postsearch	Participant
	Verbal responses to several questions	Stimulated PostSearch Interview	Postsearch	Participant & Researchers
2. How do perceptions of disorientation interact with the strategies employed?	Protocol	Think-Aloud Protocol	Search	Participant
	Audit Trail	Video tape	Search	Participant
	Written responses to several questions	Postsearch Questions	Postsearch	Participant
	Verbal responses to several questions	Stimulated Postsearch Interview	Postsearch	Participant & Researchers
3. How does perceived self-efficacy affect the strategies employed?	Written responses to several questions	Presearch Survey	Presearch	Participant
	Written responses to several questions	Postsearch Questions	Postsearch	Participant
	Verbal responses to several questions	Stimulated Postsearch Interview	Postsearch	Participant & Researchers
4. How does system knowledge affect the strategies employed?	Written responses to several questions	Presearch Survey	Presearch	Participant
	Protocol	Think-Aloud Protocol	Search	Participant
	Audit Trail	Video tape	Search	Participant
	Written responses to several questions	Postsearch Questions	Postsearch	Participant
	Verbal responses to several questions	Stimulated Postsearch Interview	Postsearch	Participant & Reasearchers
5. How does subject knowledge affect the strategies employed?	Written responses to several questions	Survey	Presearch	Participant
	Protocol	Think-Aloud Protocol	Search	Participant
	Audit Trail	Video tape	Search	Participant
	Written responses to several questions	Postsearch Questions	Postsearch	Participant
	Verbal responses to several questions	Stimulated Postsearch Interview	Postsearch	Participant & Researchers
Overall Question: What strategies are employed by learners as they work in a hypermedia information system?	Written responses to several questions	Survey	Presearch	Participant
	Protocol	Think-Aloud Protocol	Search	Participant
	Audit Trail	Video tape	Search	Participant
	Written responses to several questions	Postsearch Questions	Postsearch	Participant
	Verbal responses to several questions	Stimulated Postsearch Interview	Postsearch	Participant & Researchers

Figure 3 ☐ Sample search trail



for further information (see, e.g., Glaser & Strauss, 1967; Hert, 1992). Formal analysis, comprising several reviews of the data, took place near the end of the data collection phase (Bogdan & Biklen, 1992).

Think-aloud transcripts of the audio recordings provided a verbatim record of the search session. Transcription of the video tapes involved a step-by-step reconstruction of the participant's movement in the WWW. The information gathered from the video tapes was transformed into a search trail, which included the locations visited by participants during the search. A sample search trail for a study participant is illustrated in Figure 3.

Preliminary analysis took place as transcripts

Table 3 ☐ Sample search script

Action/Location in the WWW	*Think-Aloud Protocol*
Selection of search engine: WebCrawler	We'll try another one. Another engine. That was taking forever. Let's try WebCrawler. Should have more luck with this one—I hope! I tried this one last nite. It wasn't as bad as this Lycos. Okay.
Enter search term: "emotional handicapped"	Let's look under emotional handicapped. Search for that. I wonder if you have to lower this 35. I was looking at that last nite and it was interesting to me. You could probably narrow down your results if you didn't want to sit here and wait for the system to find 35 return documents. Or I am assuming that's what that is. Anyway, I hope I am talking loud enough here for you to hear what I am saying.
Presentation of WebCrawler results	Okay. High load on the WebCrawler.
Selection from hit list: DealerNet	So, okay, so it is sponsored by these people, so let's go into DealerNet and see. Oh, gosh, yeah. I don't think this is where I want to be. About DealerNet Rent a Car. This is so funny. Okay. This is not where I want to be.
Selection of *Netscape*® option: History	Okay. Let's go down here. Okay. I am going to go back and see where I was before. And that was WebCrawler.
Selection of search engine: WebCrawler	Okay. Let's go back to WebCrawler. I used the history to go back um under go.
Enter search term: "reading"	Okay, let's see. Let's try another topic. Um . . . sigh . . . okay. Let's try something more generic. Maybe I can get into emotionally handicapped after I get into the reading subject.
Presentation of WebCrawler results	Number of . . . Right where I was before . . .
Selection from hit list: Outside On-line	Okay, let's try Star . . . I tried DealerNet and it was about cars. Interactive on-line thing. Okay, I am reading through this. Okay. Okay. This is a lot of reading . . . Let's try Star Corporate. All right. This is where I was before.
Selection from WebPage: Map of Seatac Airport	A map. Let's try a map and see where we are going. Yeah, that's not what I wanted. This is so funny. Okay, we'll go back. Using the history [back button].

were generated. A participant summary sheet was used to summarize the analysis and to assist in organizing the data (McGregor, 1993; Miles & Huberman, 1984). The summary sheet related each research question to the instrument(s) examined, aiding in the linking of data to metacognitive knowledge, perceived self-efficacy, system knowledge, and subject knowledge.

Stimulated postsearch interviews were scheduled one week after completion of data collection; one hour was allotted for each interview. Initial analysis of the think-aloud protocols and search trails helped to guide the formulation of additional questions appropriate for individual interviews. Videotapes were shown during the interview to stimulate recall of particular instances in the search process.

In-Depth Analysis

Individual Cases. Before beginning in-depth analysis, think-aloud protocols and search trails were combined to generate scripts. A sample script for a study participant is shown in Table 3. A "script" format, often used in screen plays, movies, and television, was used to link the elements of what was displayed on the screen and the participants' verbalizations. This enabled the linking of the participants' location in the WWW with their verbalizations.

Examination, categorization, tabulation, and recombination techniques were used throughout the in-depth analysis. As shown in Table 4, implementation took place during several stages. Each instrument was examined carefully,

Table 4 ☐ Stages of in-depth individual case analysis via read-through

Stage	*Researcher Action*	*Result*
1	Read through all instruments	Notes and ideas related to emerging themes
2	Read through all instruments	Identify plot or overarching theme
3	Review notes	Additions to notes related to emerging themes
4	Read through all instruments	Themes and patterns identified
5	Read through all instruments, guided by research questions	Data highlighted according to research questions
6	Read through identified themes and patterns, comparing to established strategy list	Strategies related to themes and patterns identified
7	Read through data highlighted according to each research question, comparing to established strategy list	Strategies related to research questions identified
8	Read through all instruments	Action and decision points identified
9	Read through identified actions and decisions, comparing to established strategy list	Strategies related to actions and decisions identified

and themes and patterns were identified during each reading. During this phase, each participant was analyzed as an individual case; i.e., each participant's instruments were "read" as a complete set. Reading enables the researcher to gain a broad orientation toward the data, as well as to gain indications for further analyses (Bogdan & Biklen, 1992; Yin, 1994). During the first five stages of analysis, the "read through" included presearch survey, scripts, postsearch questionnaires, and stimulated postsearch interviews. Beginning with the presearch survey, each question and answer was read on all instruments and for each participant. During stages 1 through 3, points of interest were noted and plots (overarching themes) were generated. During stages 4 and 5, the focus of the read through was narrowed, yielding specific themes for each participant. Data were then highlighted using multi-colored markers keyed to the corresponding research questions (see Ericsson & Simon, 1984, for a description of the mark-up process).

The data elements examined in stages 6 and 7 involved specific instances (themes and patterns) identified in the first five stages. Using the highlighted data, instances were then coded. The codes and their associated definitions related to the actions, decisions, and strategies used by participants as they searched. Themes and patterns not readily applicable to established categories were assigned to new categories and given new codes. Code examples include: AWARERETR—awareness of retrieval technique; DECMAKING—making a decision; DISORIENT—disorientation; STRATEXPL—strategy: exploring and trying different things; STRATREFL—strategy: reflection.

Consistent with the iterative and generative nature of qualitative analysis (Lincoln & Guba, 1985), the analysis process was broadened during stage 8. As in stages 1 through 3, all data elements, actions, and decision points were identified. These actions and decision points were used in stage 9 to code according to strategy. Data were then collated according to the corresponding research questions. Each coded data source was organized by research question and reanalyzed to match and clarify patterns. Pattern matching involves detecting similarities in the thoughts and/or actions across participants (Bogdan & Biklen, 1992) to identify initial trends in strategies.

Next, participant verification of the derived profiles was initiated (see Bogdan & Biklen, 1992; Mathison, 1988). Validation of the derived profiles included themes, patterns, and strategies. To facilitate feedback, individual case

Table 5 ☐ A Sample of Marsha's Case Report

The Traveler: Biographical and Background Information

This section of the case report contained general information on the participant, including age, ethnicity, educational pursuits, and reported knowledge in the five areas examined in the study.

Destination: The Search Task

In this section, the participant's problem was discussed, including: the subject area searched and the strategy the participant planned to use while searching for the information.

Marsha started the journey with a well-defined goal and strategy in mind. Her initial goal: "I hope to find information about dinosaurs. But not real, real technical or historic information because the children that I am teaching are 3, 4, and 5 year olds. . . ." Marsha's strategy: "Just kind of search everything and everywhere."

The Journey: Exploring the Web

General Explanation of the Trip:

This section provided an overview of the participant's search: what they did, the sites they visited on the WWW, and the changes that occurred as the participant searched for their information.

She never really returned to her original search task, but, instead, completely changed her focus from "real dinosaurs to Barney®, a fictitious dinosaur. I want to find information catered to children, so I figured since Barney® was a kid thing, that he should lead me to what I was looking for. . . ."

General Themes and Patterns:

This section contained specific information on the participant's search, including themes and patterns established by each participant as they search for information on the WWW.

Despite the apparent "wishy-washy," lack of focus and control to Marsha's search, there was an underlying theme throughout: her classroom. Marsha does indeed go on several tangents, and there is a lot of action, *but she is connecting it through prior knowledge and experience to her classroom. . . .*

Overall Themes and Patterns

This section outlined overall themes and patterns emerging from each participant's search.

Low self-confidence in using technology, Confusion over what she wanted to do

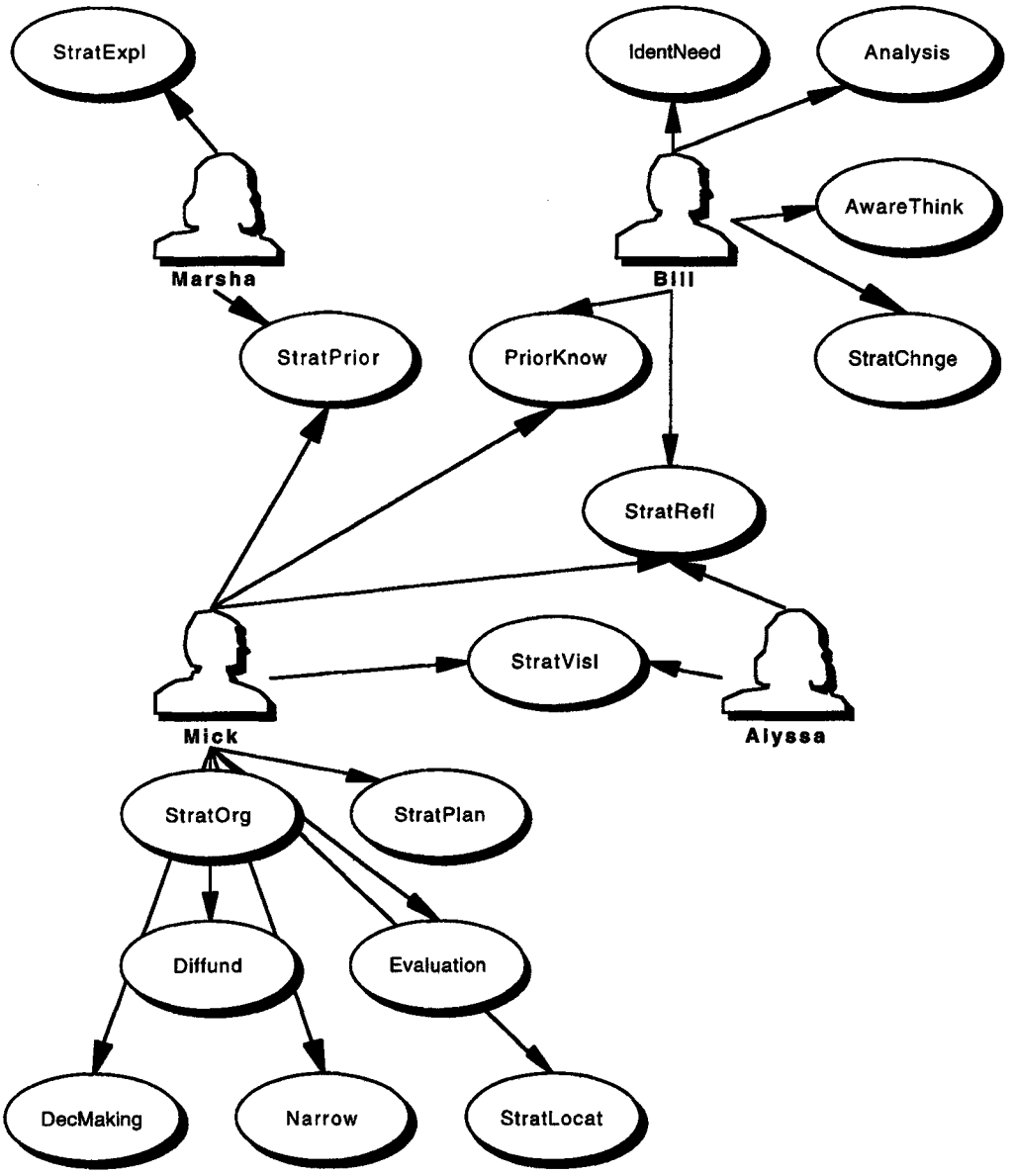
reports were generated. A standard structure, depicted in Table 5, ensured consistency in the information provided to, and the organization of comments from, each participant who was asked to review the report and to generate questions or concerns for discussion with the researchers.

One week later, the first author met individually with participants to discuss the case reports. Results indicated a high degree of researcher-participant agreement. Recommendations from each participant were noted during the interviews; where indicated, changes and/or additions were made.

Cross-Case Comparison. Analysis of global patterns and trends was necessary to address the overall research question. Two methods were used: aggregation by episode and aggregation by process (Ericsson & Simon, 1984). In aggregating the data, individual cases were merged into a single instance. As illustrated in Figure 4, aggregation focused on similar episodes within searches and similar processes used across participants. For example, while Mick engaged in several unique strategies (organizing, planning, evaluating, etc.), he also used strategies similar to those used by other participants, including reliance on prior knowledge, reflection, and visualization. The identification of cross-case strategies was essential to determining the generality of strategies used.

Cross-Case Data Accumulation. The final phase of the analysis process involved cumulative data analysis, where cross-case trends, issues,

Figure 4 ☐ Aggregation of individual cases



and themes were examined as complete units (Lincoln & Guba, 1985). During this phase, trends and themes from the cross-cases analysis were categorized according to the research questions. From these data, interpretations of the strategies used by participants were generated by the researchers based on analysis of all data elements.

FINDINGS AND DISCUSSION

Given the nature of qualitative analysis, as well as the amount of data presented, findings and interpretations are discussed together. The discussion focuses on the four participants for whom detailed analyses were conducted, and is not intended to be generalized beyond the scope of this study.

Table 6 ☐ Summary of participants reported knowledge and overall rating of "success"

Participant	*Metacognitive*	*Disorientation*	*Self-Efficacy*	*System*	*Subject*	*"Success" Rating*
Alyssa	mid	high	low	low	mid	no
Bill	high	mid	mid	low	mid	yes
Marsha	low	mid	mid	low	low	no
Mick	high	low	high	low	high	yes

Distinctions Among Participants

Participant ratings are summarized in Table 6. The ratings reflect self-reported perceptions on the various measures and overall success. To protect the identity of the participants, pseudonyms are used. The descriptors provided for participants indicate an overall theme for their search. Themes were generated during the analysis process.

Alyssa: The Mapless Traveler

Alyssa was an undergraduate special education major in her early 20s. She was employed full-time and was in the final year of undergraduate studies. Alyssa reported being a novice in the use of hypertext and hypermedia applications. She had used other information-retrieval technologies, such as ERIC and electronic card catalogs, but had employed only basic search techniques. She had performed all types of searches (subject, author, title, keyword), but had not used Boolean operators (e.g., and, or, not), and stated she ". . . didn't know they existed." Alyssa rated herself low in system knowledge.

Alyssa indicated metacognitive awareness. During the presearch survey, where participants described how they would "make a pizza," she reported, "I had to think about what I had already put on the pizza and what I still had left to assemble." Alyssa rated herself as possessing midlevel metacognitive knowledge.

Alyssa rated her perceived self-efficacy as low. She reported feeling confused by computer technologies and uncomfortable in her ability to use them. One exception was word processing, with which Alyssa reported feeling very confident. Alyssa also reported awareness of professional benefits for knowing and using computer technologies in general. She reported little ability and confidence in the use of information-retrieval technologies, and that she was very uncomfortable using systems like *Netscape®*. In addition, Alyssa reported low confidence in her ability to select key terms for an information search, and expressed doubt in her ability to complete the search task.

Alyssa's choice for her search task was: "What are the components of a good reading lesson for emotionally handicapped students?" She reported feeling somewhat knowledgeable in this topic, as she planned to teach in this area after completing her degree. Alyssa rated herself as possessing midlevel prior subject knowledge.

Alyssa's goal was to: ". . . retrieve at least three articles that dealt with reading or the teaching of reading to students with emotional handicaps." Her strategy: ". . . go into Netsearch. Select an engine, type in my keywords and click search. That's it!"

Bill: The Divergent Directed Traveler

Bill, a substitute teacher in his late 40s, was enrolled in a special, K–5 certification program designed to recruit individuals to the teaching profession. In addition to substitute teaching, Bill owned a landscaping company and professed a personal interest in gardening.

Bill rated himself as a relative novice in the use of hypertext and hypermedia applications. He had used other information-retrieval technologies such as ERIC, and reported having previously performed subject and keyword searches. Bill rated his prior system knowledge as low based on his limited use of *Netscape®*, but had previous experience with related systems. During the search task, Bill referenced previous search experiences to inform his actions in

Netscape®. He appeared to acquire system knowledge quickly, using this knowledge to guide his search.

In the questions following the pizza-making description exercise on the presearch survey, Bill reported: "Yes [I was monitoring what I was doing], so [I] would not put on more ingredients than needed so [the] company could make a profit." Bill rated himself high in metacognitive knowledge, and rated his perceived self-efficacy toward technology as midrange. He reported feeling somewhat confused by, and anxious over, computer technologies, and as feeling somewhat uncomfortable in his ability to work with them. Like other students in the class, however, Bill had prior experience with word processors, with which he reported feeling very confident. Bill also reported awareness of professional benefits in knowing about and using computer technologies.

Bill reported high ability and confidence in information-retrieval technologies. He indicated feeling comfortable using systems like *Netscape*® and in selecting terms for an information search. Bill also expressed confidence in his ability to start and successfully complete his search. Bill's search task was to, ". . . look for basic information for children (in grades 3–5) to learn about plant life."

Bill's goal was to ". . . provide facts children can use for their own search in school to augment existing books in the library about plants, plant growth." When asked about his strategy for searching, Bill responded: ". . . [I will] select Netsearch [from the button row to choose a search engine], select WebCrawler, enter name of topic 'photosynthesis' and/or plant growth, plant life. . . ." He identified where to begin his search and several keywords to be used.

Marsha: The Explorer

Marsha, in her early 20s, was completing her first year in a master's degree program in early childhood education. In addition to attending classes, Marsha was a full-time teacher of a pre-K, ESL (English as a Second Language) class in a rural elementary school. Marsha rated herself as a novice in the use of hypertext and hypermedia applications. She had used other information-retrieval technologies extensively, including ERIC and electronic card catalogs. However, Marsha reported she had not progressed beyond basic search techniques. She had performed various types of searches (subject, author, title, keyword), but had not used Boolean operators ". . . because I didn't know how to." Marsha rated herself low in system knowledge.

Marsha reported a lack of metacognitive awareness, and rated herself low in metacognitive knowledge. During the pizza-making exercise, Marsha reported not monitoring what she was thinking. Marsha's perceived self-efficacy toward technology was in the mid-to-low range. In general, she reported feeling very confused and anxious toward computer technologies and somewhat uncomfortable in her ability to work with them (except for word processing). Marsha also reported awareness of professional benefits in knowing and using computer technologies in general. When rating her ability and confidence in information-retrieval technologies, Marsha reported feeling somewhat uncomfortable using *Netscape*®. On the other hand, she reported confidence in her ability to use information-retrieval technologies, including selecting search terms, getting started, and successfully completing a search task.

Marsha's search focused on: "How and what to teach very young children (3- to 4-year-olds) about dinosaurs." She reported wanting to provide factual information to balance the information about a fictional purple dinosaur: "I hope to teach them some factual information about dinosaurs so that they can associate that those [dinosaurs] were real animals, not just BarneyR." Marsha reported feeling ". . . a bit green" in the topic area, rating herself low in subject knowledge. Her initial goal was ". . . to find information about dinosaurs. But not real, real technical or historic information because the children that I am teaching are 3-, 4-, and 5-year-olds and they are mentally delayed. So they are real, real young, but they have a natural fascination with dinosaurs and, of course, because of Barney®." Marsha's search strategy included, "Just kind of search everything and everywhere. I am not really familiar with a lot of things so any search units associated with education and children I will probably open up and see."

Mick: The Focused Traveler

Mick was a communications major in his early 40s completing coursework toward a PhD. In addition, Mick was a teaching assistant and script consultant. He had prior experience using hypertext and hypermedia applications, specifically *HyperCard®*. Mick reported extensive experience using other information-retrieval technologies, including the ERIC and PsychLit databases and electronic card catalogs. Mick reported applying advanced search techniques with these applications, not only performing varied types of searches (subject, author, title, keyword), but using Boolean operators extensively to ". . . narrow the focus of my search."

Mick's lack of experience with *Netscape®* resulted in a low self-rating in system knowledge. However, his prior experience with technology, though not directly related to *Netscape®* and WWW technologies, aided his search. He appeared to quickly acquire specific system knowledge of *Netscape®*. Mick also indicated awareness of metacognitive knowledge. During the pizza-making exercise, he monitored what he was thinking, visualizing the procedure as he wrote it out. Mick rated himself high in metacognitive knowledge.

Mick's self-reported confidence with technology was very high. He reported no confusion or anxiety toward computer technologies, and indicated comfort in his ability to work with them. Mick's reports were mixed (medium, high) in his ability and confidence in using information-retrieval technologies. Although he reported being very comfortable using systems like *Netscape®*, he also indicated he was somewhat uncomfortable selecting search terms. In addition, Mick reported being only somewhat confident in his ability to start and to successfully complete his search. He reported a high level of subject-area expertise and rated himself high in prior subject knowledge.

Mick attempted to locate script-writing material for his communications class: "I am . . . looking for material that I can utilize in my media class. I want to see if there is any screenplay material on line." Mick's strategy: ". . . use the search drivers that were pointed out and discussed in our class—had keywords thought out (e.g., screen play)."

Results By Research Question

Overall Research Question: What strategies are employed in open-ended hypermedia information systems?

Three overall trends emerged:

1. A variety of strategies were used by learners as they sought information in a hypermedia information system;
2. Metacognition, system, and subject knowledge affected strategy choice and utilization; and
3. Perceptions of disorientation, as well as perceived self-efficacy, affected strategy choice and utilization.

Discussion of overall trends is provided in the context of the five secondary questions.

Question One: Does metacognitive knowledge affect the strategies employed?

Of the knowledge areas examined, metacognitive knowledge appeared to most influence strategy use. Participants with high metacognitive knowledge appeared better able to reflect on their search processes, which enabled them to refine their actions and make better use of the system. Participants who used the system effectively were active information processors and comprehenders who monitored their learning activities, processes deemed critical for developing understanding (West, Farmer, & Wolff, 1991).

Participants with high metacognitive knowledge also appeared better oriented to the system. Mick, for example, consistently monitored his thinking and revised his actions accordingly. He engaged in several key metacognitive tasks described by Wang, Haertel, and Walberg (1990) as important for learning and understanding: comprehension monitoring, use of self-regulation and self-control strategies, and use of these strategies to facilitate generalization. Mick's metacognitive skills were fundamental to his success.

Mick provided several examples of metacognitive knowledge usage. One example occurred at the beginning of his search task, when Mick questioned his terminology:

I have to think of my keywords here. I think if I say script, that might be a little too broad and I might end up getting different scripting, like toward software programs. And maybe not just television writing. . . .

Another statement reinforced Mick's use of metacognitive strategies:

I am probably spending too much time in this particular driver. I should probably try another one. Let's try television. Um . . . Well, maybe I am wrong. Maybe . . . I am just using an inappropriate key. . . .

Bill also demonstrated metacognitive awareness throughout his search. He relied on metacognitive knowledge while attempting a new strategy:

Well, I don't know what this is. See what happens. Plants. See what happens when I select plants. Land plants. None of this info is giving me the depth that I wanted for elementary school students. This is way too advanced. So I will have to go to another source. . . .

Bill also relied on metacognitive knowledge when he was confused:

So . . . oops. Pressed the wrong button. What is going on here? Now Thursday, when this happened, all I had to do is come here and go down to there, it brought me down to where I was. Now I will use the bookmark. Now I don't need this. And I really don't need this. . . .

In contrast, Alyssa demonstrated little use of metacognitive knowledge. Although she reported midlevel cognitive awareness on the presearch survey, it was not evident in her search. Her search session was marked by apparently random actions:

Guess I didn't make my topic specific enough. I am not sure why it gave me this thing . . . when I first tried this yesterday, it wouldn't bring up my subject. So this is the first time I actually got results. And I am just looking at all this stuff and it doesn't make sense as to why they are giving it to me. . . . I wanted to teach a reading lesson, but it has to be really specific to students with emotional handicaps because I am not teaching regular students. That's what I was trying to look for. So I started with emotionally handicapped to see if I could work my way down, or cross reference it somehow. . . And I am not sure what this is helping me do. . . .

While all participants reported metacognitive activity during their searches, the effects varied. According to Flavell (1979), a metacognitive experience is any conscious cognitive experience that accompanies and pertains to an intellectual enterprise. His description is consistent with this study: "To illustrate, you may experience a momentary sense of puzzlement that you subsequently ignore, or you may wonder for some time if you really understand what another person is up to" (p. 908). Both the sense of puzzlement and wonder about understanding were experienced by each participant.

Interestingly, the manner in which metacognitive experiences are processed impacts whether, and how, metacognition influences action. As Flavell (1979) writes:

Some metacognitive experiences are best described as items of metacognitive knowledge that have entered consciousness. As one example, while wrestling with some stubborn problem, you suddenly recall another problem very like it that you solved thus and so. Some metacognitive experiences clearly cannot be described that way, however. For instance, the feeling that you are still far from your goal is not in itself a segment of metacognitive knowledge, although what you make of that feeling and what you do about it would undoubtedly be informed and guided by your metacognitive knowledge . . . (p. 908).

This interplay between metacognitive knowledge and prior subject knowledge differentiated Mick from other participants. His extensive prior subject knowledge both augmented, and was influenced by, his metacognitive knowledge. The interplay between factors (e.g. metacognitive knowledge and prior subject knowledge) was common. As illustrated in Figure 5, participants engaged many strategies during their searches. For example, Alyssa's deployment of metacognitive knowledge was apparently impaired by other factors, including disorientation, frustration, and impatience. This finding is consistent with Derry's (1989) observation that successful learners assess situational requirements and develop plans to deal with them. Alyssa's inability to deploy metacognitive strategies or to develop plans made completion of her task especially problematic.

The importance of metacognitive knowledge has been well-documented (see, e.g., Brown & Palincsar, 1989; Paris, Cross, & Lipson, 1984).

Yet, methods for assisting learners in refining their metacognitive knowledge are not readily apparent. Some have advocated the teaching of specific metacognitive skills (Osman & Hannafin, 1992); others have trained students to effectively monitor their learning (Brown & Palincsar, 1989; Paris, et al., 1984). Still, recommendations for teaching or training are often equivocal and difficult to substantiate empirically. While results of this study support the importance of metacognitive knowledge, further investigation is needed to facilitate the utility of metacognitive knowledge and skill in open-learning environments.

Question Two: Is perceived orientation influenced by the strategies employed?

User orientation appeared to influence the strategies observed and reported. At times, each participant reported feeling "lost" or "being in the middle of nowhere" while searching on the Web. Disorientation, in turn, affected individual search decisions. High levels of disorientation caused significant dissatisfaction with the search process. For some, this not only increased frustration, but also became debilitating.

Several researchers have discussed the consequences of disorientation on usability (see, e.g., Jonassen & Grabinger, 1990; Marchionini, 1988). Significant disorientation may hinder the user's ability to reference relevant prior subject knowledge as well as metacognitive knowledge. Disorientation also tends to lower the user's perceived ability to succeed, resulting in lower confidence and task persistence (Beasley & Waugh, 1995; Tripp & Roby, 1990).

Alyssa's high levels of disorientation and dissatisfaction provide compelling evidence of these effects. Her failure to retrieve relevant information, paired with her use of primitive search strategies, suggest that disorientation seriously hampered her search. Phrases such as: "I am getting nowhere" and "I am going everywhere but where I need to be," were typical of her think-aloud comments. Even when Alyssa perceived progress, disorientation was evident:

> Let's just try libraries. Information, business and law, science and engineering. Let's try information on library studies. Hours. Yeah. This is not working. I am not getting anywhere! It's not doing anything. Okay. Let's just return back to the HomePage. Oh, let's try Yahoo. I have not tried Yahoo. Let's try education. I do not know how I got here, but I got here. . . .

This study provided further evidence of being "lost in hyperspace" (Berk & Devlin, 1991). On repeated occasions, Alyssa indicated she felt confused and needed a map. Bill also reported some disorientation, occasionally voicing uncertainty:

> Go to the next source by going back. I forgot what I even selected. I forget how I got to SAPS. I forget how I got here. SAPS as an experiment is something I could use. Janette—copy of response to seedlings to light. Be able to see what happens when they remove the sunlight from seedlings. Just don't remember how I got to SAPS. . . .

Bill also indicated a lack of awareness of how he influenced the system's output:

> [I am] not really sure of what is happening here, but it doesn't look like it is giving me anything.

Marsha also expressed some disorientation, but it was not debilitating:

> Let's see the kids' Web. That would be good. This better be good. It should have stuff that kids created. Oh, let's see . . . where am I. Some thing where the kids created everything. Come on host, connect me. I would think it would be the same host. It is all on the same page. Ooo. They couldn't locate the host. That wasn't nice. . . .

Her confusion often related more to the absence of a response than to the information retrieved:

> Oh, dinosaurs. Why does it do that? If I click on it, I would think it would show up. I clicked on the wrong one. Oh, well, no, I did it. It is 307K so it will take *forever* for the picture to come up! I don't understand why I just couldn't get Barney® on mine. What was the lady out in Texas thinking? Okay. Almost done. It's just a picture. . . .

Like Bill, Marsha's perceived orientation enabled her to continue her search task.

Mick, on the other hand, displayed very little disorientation. Throughout his search, disorien-

tation surfaced only twice in the protocol: once when something was not found and he received an error message, and a second time when he became confused as to how he arrived at a certain point:

What does this do? Some sort of FTP . . . Okay. What is the deal with this? Shooting script. Army of Darkness. Now see, that didn't have a specific heading and it is definitely a script. I have no idea of how on earth I got here. I need to go peek at how that was listed. I don't remember it saying it was a script. And it is still loading. Okay is it done? Yes. Okay. This is a full blown shooting script for the Army of Darkness. Off-shoot of the Evil dead. . . .

Mick's reaction to disorientation differentiated him from other participants. Rather than being deterred, he continued with his task, relying on his extensive knowledge in other areas to guide and refine his approach.

Question Three: Does perceived self-efficacy affect the strategies employed?

Perceived self-efficacy affected both the number and types of strategies engaged. Those who perceived medium (Bill and Marsha) to high (Mick) self-efficacy engaged in more strategies and at higher levels than the low self-efficacy participant (Alyssa). Alyssa's lack of confidence resulted in low-level searches to simply locate information. This finding is consistent with studies on the relationship between self-efficacy and performance, where high self-efficacy participants engaged in more exploration of the system (Ashton, 1984; Kinzie & Delcourt, 1991; Murphy, 1988). Increased exploration appeared to create more opportunities, increasing the participants' prospects of locating the desired information.

Perceived self-efficacy affected not only the nature of the interactions, but also perceptions of control. Both Bill and Mick reported high perceived self-efficacy and were successful in their task. Throughout the search, Mick tried several different approaches and expressed a high degree of confidence. When asked about a decision regarding scripts he was examining, Mick offered the following response:

Mick: Well, most of the stuff that I found so far is legitimately formatted. But there are a couple of scripts that apparently users up-loaded—they put the format into a user-friendly format and it is not accurate.

First Author: This is really interesting to me. 'Cause you found one. . . .

Mick: Yeah!

First Author: For the *Star Wars* stuff. But you never went back and tried to find another one for this movie series, for some reason. Any particular reason why?

Mick: Uh, let me see what the script looks like. Uh . . . I think that might be part of it [the reason he didn't return].

First Author: Okay.

Mick: Well, I'll tell you the other part of it. There was a script that I found, but it was not properly formatted. So I didn't want to waste my time looking at those, I wanted one that was properly formatted. I wanted a *real* script. . . .

Although Marsha was unsuccessful in her search, her high confidence and perceived self-efficacy helped her to identify other useful information. She found several related resources that she subsequently intended to use in her class. Bill utilized other abilities to guide his search, such as persistence and domain knowledge. While he indicated some lack of control and understanding, it did not seriously hamper his effort.

Alyssa, in contrast, consistently demonstrated low perceived self-efficacy which, in turn, influenced her interactions and strategies. She often voiced uncertainty as to how to proceed, and was unable to evolve her understanding of the system. She perceived herself as "trapped by the system." This lack of confidence in her abilities was reflected in her repeated statements of self-doubt and requests for guidance:

. . . Guess I didn't make my topic specific enough. I am not sure why it gave me this thing. It's not done! . . . I am just looking at all this stuff and it doesn't make sense as to why they are giving it to me. . . . It has nothing to do with what I want . . . I am not sure what this is helping me do. . . .

Question Four: Does prior system knowledge affect the strategies employed?

The level of system knowledge had a stronger apparent influence on strategy use than prior subject knowledge. This outcome is consistent with Park and Hannafin's (1993) conclusion as to the importance of establishing a functional

mental model of open multimedia systems. Participants with low system knowledge engaged in more primitive search strategies than those with high system knowledge—even though some possessed significant prior domain knowledge. While increased system knowledge alone may not ensure success, it is critical to selecting terms and knowing how to interact, as well as to reducing disorientation and frustration. Participants who quickly developed system knowledge were better able to quickly develop strategies for finding their information.

Inadequate system knowledge inherently limited system use. Marsha's statement typified the dilemma:

> There is probably some faster way to do it [going back], but I know you can do it this way [using the back key].

The use of the back key in *Netscape®* required more time to navigate through the system than otherwise necessary, increasing frustration and disorientation levels. Alyssa's comments reflected similar uncertainty:

> Okay. What does this have to do with my topic? This is too long. I have no patience for this . . . This is taking forever. I guess I could have used the back and forth key . . . This is taking so long. . . . Let's try the forward key and see if that work. And the forward key is not working. Okay, let's just keep going . . .

Although Mick had not previously used *Netscape®*, he had worked with other hypertext and hypermedia systems. He appeared to possess a general orientation to their operation. For example, Mick was able to query the system and react accordingly:

> I am probably spending too much time in this particular driver. I should probably try another one. Let's try television. Um . . . Well, maybe I am wrong. Maybe . . . I am just using an inappropriate key. . . .

Unlike Alyssa, whose low system knowledge and high frustration became debilitating, Mick controlled the environment. He generated his own questions related to his activities and interpreted system output accordingly.

Bill's interactions provide good examples of how system knowledge evolves through usage. Initially, he was unaware of how to use the pointer to click on objects he wanted to retrieve; yet, he quickly resolved the problem:

> Enter in photosynthesis. Guess that is spelled right. Nope. No it isn't. Try again. Photosynthesis. Okay. The mouse doesn't work. Have to use the return button. Okay. Lesson learned. Found 58 documents. 35 returned. Trying to decipher the information here. . . . There is plant nutrition. Possibly something. Life of a tree. That's one that kinda sounds photosynthesis. I did not want that one. I did not want that one. I will stop that one. Can I back up? Yes. Good. Oops. Did it again. Back up. Go back. There you go..You put the finger on it and that works much better than the palm. . .

During the interview, participants were asked to describe the mental image they had (if any) of the WWW. Bill and Mick were able to describe and depict their mental models of the system, but neither Marsha nor Alyssa could do so. Mayer's (1989) work on conceptual models provides an interesting interpretative framework. He found that in studies where conceptual models were provided, learners with low prior knowledge were able to make significant strides in problem solving and understanding. The availability of the model enabled them to proceed in ways not previously possible. Learners with high prior knowledge, in contrast, often constructed their own mental models. For these learners, external models often led to conflict and lowered performance. While participants in the present study were not provided a model prior to the search task, those who generated their own engaged in more advanced (and successful) strategies.

Question Five: Does prior subject knowledge affect the strategies employed?

While the participants used a variety of strategies independent of their prior subject knowledge, those with limited subject knowledge engaged in more primitive search strategies, relying heavily on a few key terms. These findings support the conclusions of several researchers: learners with extensive prior knowledge outperform their cohorts with limited prior knowledge (Langer & Nicolich, 1981; Recht & Leslie, 1988). Prior subject knowledge assists the learner in generating terms that may be relevant to their specific search topic. In this study, the ability to generate and recognize related terms influenced what was pursued in the system and, in turn, how the system was used.

Prior subject knowledge also appeared to

affect the ability to integrate and retain new information. Bill, who possessed significant subject knowledge, refined his search using previously attempted terms. Marsha, who possessed little prior subject knowledge, refined her search little, using few new or alternative terms. High subject knowledge enables learners to utilize a variety of terms as they search for information. They not only possess knowledge of common terms associated with the field, but may also possess a wealth of related terms and concepts.

Bill, Mick, and Alyssa made use of several terms, while Marsha used a limited set. While the number of terms used during the search process was not a strong indicator of success or failure, it could indicate difficulty in monitoring and judging the relevance of system output in relation to information sought, as well as limited knowledge of how to manipulate the system to refine the search. Hansen (1986) reported a similar result with naive searchers looking for information from both print and electronic sources. The ability to utilize "hit lists" (i.e., the results presented by the information system to the learner) to refine a search, adapting terminology and the search task (i.e., changing search terms, search engines, etc.), are crucial to the successful retrieval of information.

According to Ausubel (1963), the ability to integrate and transform information is crucial to performance. The integration and transformation of information involves the learner's ability to relate new information to prior knowledge. Even if participants located the information sought, their ability to evaluate its veracity and judge its relevance was limited. Failure to integrate and transform the information accessed during a search often caused conflicts with both performance and search success.

Mick provided examples of this phenomenon throughout his search. On several occasions the information he sought was displayed in the hit list; however he was not able to identify it as the information he sought. During the stimulated postsearch interview, he expressed disbelief that he overlooked the information and failed to recognize it, review it critically, relate it to existing knowledge, and examine it from multiple or competing perspectives. While Mick was ultimately successful in his search, the inability to integrate and transform information could lead learners to perceive failure in a search task, when, in fact, the information they seek is available.

IMPLICATIONS AND RECOMMENDATIONS

Several implications and recommendations can be drawn from this study. Disorientation played a significant role in system use, a problem cited as a significant issue in the use of OELEs (Hannafin et al., 1994). In the present study, perceived disorientation inhibited OELE use, leading to reported discomfort and confusion. Disorientation tended to inhibit effective and successful use of the system.

The contrast between Mick's successful search and Alyssa's unsuccessful search session may reflect the extensive cognitive requirements of open-ended learning. Mick, who possessed metacognitive strategies, as well as the knowledge base (system and subject) and a high degree of self-efficacy, reported very little disorientation and was able to fully engage in the browsing and searching process. While Alyssa possessed some subject knowledge, her low skill in the other areas, along with her high degree of disorientation, limited the effectiveness of her browsing and searching. Although research is needed to confirm this finding, it may be critical to reduce perceived (or real) system discomfort and disorientation prior to advancing open learning applications. Helping learners to construct a functional mental model of the system, and providing searching tips, should increase their chances of success in finding desired information.

Two cognitive operations, integrating and angling, appear to be integral to the success of OELEs (Duchastel, 1990). Duchastel's definition of integration involves the assimilation and accommodation of new information into existing schemata. Angling is the ability to view information from different perspectives. For example, angling enables the learner to determine the potential usefulness of Web Sites that are not directly related to the key terms used. Awareness of these skills and the ability to manipulate them appears to be crucial for monitoring activities

and improving orientation in OELEs. If so, it may become critical to promote the development and use of metacognitive strategies.

Learner control is another area requiring investigation. Previous studies have indicated that the success of user control varies according to learner characteristics such as aptitude and prior knowledge (Cho, 1995; Ross & Rakow, 1981; Shin, et al., 1994). Extensive learner control may inhibit success in some electronic learning environments, since learners often do not select wisely when given open-ended choices (Romiszowski, 1990). Based on the present study, learner choice appears to significantly influence the success of OELEs: learners who developed good system knowledge successfully completed their searches, while those with low system knowledge were unable to develop system knowledge, expressed disorientation, and were unsuccessful. While research is needed to confirm these preliminary interpretations, teaching strategies for finding information in open information systems like the WWW may assist learners in their tasks.

A final implication relates to how individuals think and process information in traditional versus open learning environments. Conventional school activities may encourage "compliant" thinking (McCaslin & Good, 1992); traditional education has been largely externally managed and teacher-directed. This creates a fundamental problem for OELEs that emphasize exploration and learner-centered thinking. OELEs afford opportunities to access (and encourage this access) to a vast array of resources in a variety of formats. Traditional methods may engender generations of learners who are ill-equipped for OELEs, where individual control, divergent thinking, multiple perspectives, and independent thinking are crucial (Driscoll, Lebow, Hill, & Rowley, 1994). The epistemic beliefs, or general assumptions, students hold about the nature of learning may prove to be the root issue in the utility of complex, open-ended learning (Feltovich, Spiro, Coulson, 1989; Schoenfeld, 1983; Schrommer, 1993, 1994). Previous research in hypertext environments suggests that effectiveness differs among learners with different epistemic beliefs (Jacobson, 1990; Jacobson, et al., 1995; Jacobson & Spiro, 1995) Efforts to foster divergent thinking and multiple perspective building, as well as critical thinking and problem solving, are needed to assist learners in adapting these environments.

As open-ended hypermedia information systems grow, both in their capabilities and affordances, the need to better support learners becomes increasingly critical. The promise of hypermedia and OELEs has been widely heralded, but the potential has yet to be realized. Balance is needed between the efforts to refine the structure and features of OELEs, and efforts to empower individuals in their use. □

Janette R. Hill is with the Department of Educational Technology at the University of Northern Colorado. Her e-mail address is: hill@edtech.univnorthco.edu. Michael J. Hannafin is with the Learning and Performance Support Laboratory at the University of Georgia. His e-mail address is: hannafin@coe.uga.edu.

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