FACTORS INFLUENCING THE USE OF COGNITIVE TOOLS IN WEB-BASED LEARNING ENVIRONMENTS
A Case Study

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High demands on learners in Web-based learning environments and constraints of the human cognitive system cause disorientation and cognitive overload. These problems could be inhibited if appropriate cognitive tools are provided to support learners' cognitive processes. The purpose of this study was to explore the factors influencing the use of cognitive tools in Web-based learning environments. This study used data from 31 students who attended a course delivered via the Internet. The students used 9 different cognitive tools developed in accordance with the promises of "cognitive load theory," "mental model theory," and "information processing theory." Data were collected through group interviews and questionnaires. Additionally, computer logs were analyzed to validate qualitative data. Results revealed that such factors as learning strategies, learners' prior knowledge, the usability of and orientation to tools, connectivity cost, and the content influenced learners' utilization of Web-based cognitive tools.

INTRODUCTION

There is an increasing pressure on higher education institutions to change with the information age, because of the evolving learning needs of society and the impact of new technologies on teaching and learning (Bates, 2000). The Web has the potential to meet this need of change by providing opportunities to create "well designed, learner-centered, engaging, interactive, affordable, efficient, easily accessible, flexible, meaningful, distributed and facilitated" learning environments (Khan, 2001, p. 5).

As the popularity of the Web is growing, attention to its use as a medium of learning and instruction is elevating as well. The percentage of higher educational institutions that offered distance learning courses using asynchronous Internet-based technologies was only 22% in

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1995, whereas 60% in 1997-98 academic year (Reiser, 2001). However, these institutions' approach is mostly based on the assumption that exposing learners to messages encoded in media and delivered by technology will result in learning (Jonassen & Reeves, 1996). Designers rarely take into account the cognitive processes of learners.

BACKGROUND OF THE STUDY

In Web-based learning environments, learners have the primary responsibility to access, organize, and analyze information (Jonassen & Grabinger, 1990, Newmark, 1989, citied in Iiyoshi, 1999). These high demands cause a cognitive burden on learners. Thus, cognitively ill-equipped learners feel disorientation and cognitive overload in these learning environments (Marchionini, 1988; Oren, 1990). In addition, learning is inhibited due to three major constraints of the human cognitive system: limited capacity of human short-term memory, difficulty in retrieving relevant information from long-term memory, and ineffective or inefficient use of cognitive strategies to obtain, manipulate, and restructure information (Kozma, 1992). Considering these problems and constraints, there is a necessity to support learners for constructing their personal knowledge with technology-based tools.

According to Jonassen and Reeves (1996), "cognitive tools refer to technologies, tangible or intangible, that enhance the cognitive powers of human beings during thinking, problem solving and learning." For Kozma (1987), cognitive tools are software programs that use the computer to amplify, extend, or enhance human cognition.

Cognitive tools are not designed to make learning easy or effortless by reducing information processing like the false promises of many earlier instructional technologies (Jonassen & Reeves, 1996). They are not "fingertip" tools (Perkins, 1990, cited in Jonassen, 1992) that are used naturally, effortlessly, and effectively. Instead, learners need to think harder and more meaningful by employing deeper information processing.

According to Derry and Lajoie (1993), the appropriate role for a computer system should not be a teacher or an expert, but rather a tool that extends the mind. They recommend that learners be responsible for planning, decision making, and self-regulation through the use of cognitive tools and assistance from teachers or peers. They rely on the learners, rather than computers, to provide the intelligence. Salomon (1993) states that cognitive tools have the capability to function as intellectual partners that share the cognitive burden of carrying out tasks. When computers carry out lower-level computational operations, users have more resources to engage in higher-level operations such as generating hypothesis, thinking out causal links, and drawing conclusions.

PSYCHOLOGICAL FOUNDATIONS FOR COGNITIVE TOOLS

The cognitive tools developed for this study are based on the promises of cognitive load theory, mental model theory, and information processing theory. Implications of those cognitive approaches that provided a psychological framework for the development of Web-based cognitive tools are discussed in the following section.

Cognitive Load Theory

Cognitive load theory (Chandler & Sweller, 1991; Kalyuga, Chandler, & Sweller, 2001; Sweller, van Merrienboer, & Paas, 1998;) is based on the assumption that a learner has limited processing capacity, and limitations of working memory pose a fundamental constraint on human performance and learning capacity. This theory proposes to give greater consideration to the role and limitations of working memory in instructional design. According to this theory, we can overcome the limitations of our cognitive system by schema

construction—chunking information into meaningful units—and schema automation—performing a task with minimal conscious effort. A schema that has been learned is treated as a single entity, although it may embody a vast amount of information. The benefits of schema construction are the storage of information in long-term memory that is unlimited in capacity, and a reduction of memory load. Besides, schema automation can free up the resources of working memory for other mental activities. The lack of schema construction and automation may cause cognitive overload and then may inhibit learning.

Implication 1.1: Support Memory Processes

Computers can reduce memory burden for the learner (Lajoie, 1993). According to Kozma (1992), cognitive tools can supplement limitation of short-term memory by making large amounts of information immediately available for the learner's use. For example, cognitive tools can support learners' memory processes by allowing the users to take notes or to view the steps of their learning activities by keeping tracks of these steps. Cognitive tools have the potential to help learners during thinking, problem solving, and learning by providing opportunities to share the cognitive load by undertaking lower-level operations so that resources are freed for higher order thinking skills and support memory processes (Lajoie & Azevedo, 2000).

Implication 1.2: Facilitate Schema Construction

According to Kozma (1992), cognitive tools can facilitate schema construction by making it easy to retrieve relevant, previously learned information, having it simultaneously available along with current information, and prompting the learner to structure, integrate, and interconnect new ideas with previous ones.

Implication 1.3: Assist Schema Automation

Lajoie (1993) emphasizes the importance of the automization of lower-level cognitive processes so that learners can have resources available for higher order cognitive processes. In this respect, computers can support this automization process to free up resources for higher order cognitive processes. According to Kozma (1987) experts have more automatized cognitive strategies, use less capacity of their cognitive system, and thus have more space available for learning.

Implication 1.4: Use Information Hiding

A popular method for reducing cognitive load is information hiding, which is reducing the choices visible to the user by hiding less-used options (Oren, 1990). Pull-down menus are most often used for this method, because menus lower the number of choices for users. Bookmarks and annotations are also used for reducing cognitive load, because they allow users to save parts of mental states for later use.

Mental Model Theory

Mental model theory has the goal to model and make clear human understanding of objects and phenomena during learning and other activities (Jih & Reeves, 1992). Johnson-Laird (1983) claims that "human beings understand the world by constructing working models of it in their minds" (p. 10). According to this theory, users utilize their current mental models in order to understand and predict what the system contains, how it works, how components are related, and how the system works in its way (Jih & Reeves, 1992; Sifaqui, 1999). Thus, using a system successfully is determined by how well the users' mental model represents the system (Sifaqui, 1999). However, mental models of users often vary from the conceptual model promoted by the designers because of varying prior knowledge, indi-

vidual abilities, and different beliefs about the purpose and the functions of the system (Jonassen & Henning, 1999).

As Jih and Reeves (1999) have noted, "The difficulty of understanding the structure and the functions of computer programs is especially acute when learners are given the freedom to explore hypertext materials in which the possibility of disorientation is strong" (p. 39). Disorientation has been mentioned by many researchers (Marchionini, 1988; Nielsen, 1990) as a navigational problem for hyperspace users. Users often get lost in hypermedia while they are navigating freely. Learners may not know where they are, remember the path they followed, or have difficulty in finding the information they need. The causes of disorientation are stated as the quantity of information that a user has access to and the medium's lack of physical feedback about quantity or scope. Hypermedia systems generally impose cognitive load in the form of navigation (Oren, 1990).

Implication 2.1: Facilitate the Understanding of the Learning System

Since the quality of interaction within interactive learning systems depends upon learners' construction of mental models of the systems, they are less likely to get disoriented and they are more likely to learn. Thus, it is very important to facilitate learners' conceptual understanding the structure and the functions of the learning system, because learners will need to use the system for supporting their learning (Jih & Reeves, 1992). Therefore, orientation sessions, manuals and help features should be provided for filling the discrepancy between the mental model of the user and the conceptual model of the system.

Implication 2.2: Aid Navigation

Providing some navigational aids can decrease the phenomenon of getting lost in hypermedia (Gamberini & Bussolon, 2001; Marchionini, 1988). Tools can allow the users to create hot lists by personal bookmarks, to remember their movements by navigation history, to grasp the position within the hypermedia by "you are here" type indications, and to visualize the structure of site by sitemap. Alessi and Trollip (2001) recommend designers provide site maps or some visuals devices to assist user orientation.

Implication 2.3: Guide Navigation

The problem of disorientation can diminish as users gain experience with the medium (Marchionini, 1988; Nielsen, 1990). Guided tours or orientation sessions can be used to introduce new users to how to use the site efficiently and effectively. Park and Hannafin (1993) emphasize that learners get confused and disoriented when procedures are complex, insufficient, or inconsistent. For that reason, they recommend to provide clearly defined procedures for navigating within the interactive system and accessing on-line support.

Implication 2.4: Provide Consistent Navigation

According to Hannum (2001), learners can easily become confused, lost, and frustrated when inconsistent screen designs and navigation are used. Lynch and Horton (1998) suggest that Web designers build their page and site designs on consistent patterns to make navigation easy: "A consistent approach to layout and navigation allows readers to adapt quickly to your design and predict with confidence the location of information and navigation controls across the pages of your site" (p. 56).

Information Processing Theory

Information processing theory conceptualizes how people attend to environmental events, encode information to be learned, relate it to knowledge in memory, store new knowledge in memory, and retrieve it as needed

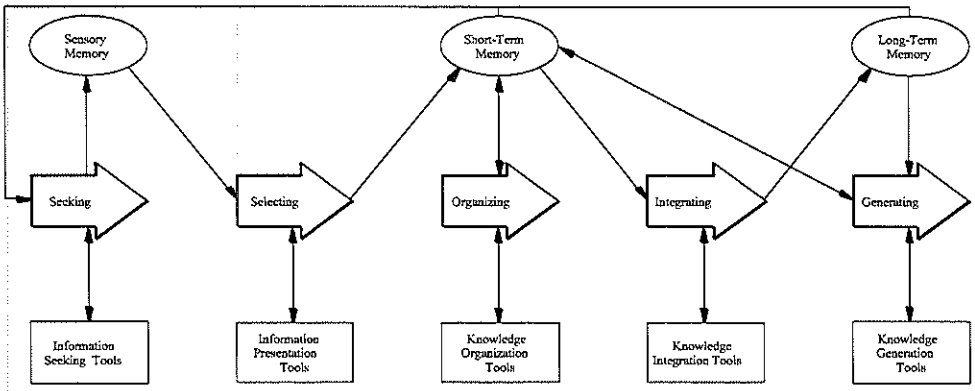

FIGURE 1
Cognitive Model of Knowledge Construction (adapted from Iiyoshi & Hannafin, 1998)

(Shuell, 1986, cited in Schunk, 2000). According to Mayer (1996), humans are active participants in the learning process who select and attend to the environment, transform and rehearse information, relate new information to existing knowledge, and organize information.

Implications of information processing theory are based on Iiyoshi and Hannafin's (1998) cognitive model of knowledge construction (see Figure 1). In this model, there are five different types of tools: information seeking tools, information presentation tools, knowledge organization tools, knowledge integration tools, and knowledge generation tools, and each tool supports a corresponding cognitive process.

Implication 3.1: Support Information Seeking

When learners try to access information from a hypermedia system, they may encounter problems such as having difficulty finding specific information, getting lost, or feeling disoriented (Leader & Klein, 1996). In this respect, cognitive tools can support learners' information-seeking processes as they attempt to identify and locate relevant information and they can help learners retrieve new and existing knowledge (Iiyoshi & Hannafin, 1998).

Implication 3.2: Help Information Selection

Learners experience some difficulties during selecting relevant information in sensory memory and combining that information to short-term memory. These difficulties are stated by Bishop and Cates (2001) as having trouble directing attention to the instructional message, isolating and disambiguating relevant information contained in the instructional message, and activating learner's existing schema by the instructional message. Accordingly, cognitive tools can help learners direct attention, isolate information, and tie into previous knowledge by appealing to learners' memories and evoking existing schema (Bishop & Cates, 2001). Selection aids such activities as underlining, highlighting or repetitive practice can be employed in this respect (McKeague & Di Vesta, 1996).

Implication 3.3: Assist Knowledge Organization

Knowledge organization is the process of establishing relationships with the selected information in short-term memory into a coherent whole (Iiyoshi, 1999). According to Schunk, when material is organized by classi-

fying and grouping information into organized chunks, it is easier to learn, and recall. Cognitive tools can help learners simplify the organization processes and eliminate unnecessary task complexity (Iiyoshi, 1999).

Implication 3.4: Aid Knowledge Integration

Knowledge integration is the process of connecting the newly-organized information to prior knowledge (Iiyoshi, 1999). When new information is associated with stored knowledge, it is more likely to be retained in long-term memory. Cognitive tools can aid learners in connecting new information with existing knowledge.

Implication 3.5: Facilitate Knowledge Generation

The last phase of information processing theory is knowledge generation. According to Jonassen and Reeves (1996), cognitive tools should represent knowledge as how someone depicts content or personal knowledge and empower learners to design their own representations of knowledge rather than absorbing representations preconceived by others. Cognitive tools can facilitate the generation of knowledge by providing opportunities for learners to represent their own knowledge flexibly and meaningfully (Iiyoshi & Hannafin, 1998).

RESEARCH DESIGN

This study is designed as a qualitative study. Qualitative studies provide a holistic and an in-depth picture of a particular individual, situation, or case (Fraenkel & Wallen, 1996). They focus on phenomena embedded in its context from the participants' perspective in their natural settings, without manipulating the environment intentionally (Miles & Huberman, 1994).

Participants

The participants of this study included 31 undergraduate students from various departments of the Middle East Technical University who attended the "Computer Networks and Communication" course. The course was offered in a hybrid format, which was a blend of face-to-face instruction with online learning materials. A significant part of the course learning was online.

In this study, purposeful sampling approach was used for the interviewing. According to Patton (1990), qualitative inquiries commonly focus in-depth on small samples to select information-rich cases purposefully. Information-rich cases enable the researcher to collect more information about the issues under investigation.

Instruments

Two instruments were used for data collection; the Learning Strategies Questionnaire and an interview guide. The Learning Strategies Questionnaire was developed to identify how often students use such learning strategies as highlighting and bookmarking in their learning activities. On this scale, items rated on a Likert-type scale of 1 to 5, where 1 represented "least frequently" and 5 represented "most frequently."

A semistructured interview guide was used in order to collect in-depth data from the learners on their perceptions of the cognitive tools. This guide was prepared in Turkish based on the existing literature and in conjunction with the research questions.

The interview guide had to goad to find out learners' purposes on using the tools, the benefits obtained by the students in using the tools, factors influencing these tools' usage, problems faced during the use of the tools, and learners' suggestions for increasing the effectiveness of the cognitive tools.

The Web-based learning environment log system recorded each and every time-stamped record of students' actions within the course

site. This log system provided a wealth of data on the activities that occurred in the learning environment without intruding on the natural learning process. Logs recorded and stored the following data: name of the student, concept number, page number, time, action name (e.g., add to bookmark), and the parameters for the action (e.g. the title of the bookmark).

Data Collection and Analysis Procedure

Data collection procedure was comprised of four sequential steps: administration of Learning Strategies Questionnaires, orientation of learners to the cognitive tools and the Web site, treatment (one-semester course), and group interviews with participants.

At the first class meeting, the instructor gave a brief overview of the course and the Learning Strategies Questionnaire was administered to the students before they were exposed to the course Web site. Then, a 15-minute orientation session was given to have participants familiarize with the course Web site and the cognitive tools.

Participants used the course Web site and the cognitive tools for a semester. All user activities on the course Web site were recorded by the system.

At the end of the semester, students were interviewed in groups of four or five. A total of five interviews were conducted, and each interview took 45 to 75 minutes.

The data collected through group interviews were subject to a content analysis and analyzed in the following manner. First, the data was labeled through using descriptive codes to simplify the thickness and complexity of the data. Then, the codes were categorized under manageable themes. Finally, those themes were used to identify the factors influenced the use of cognitive tools.

COGNITIVE TOOLS

The cognitive tools, developed and embedded in the Web site of the course "Computer Networks and Communication," were *Highlight*, *Bookmark*, *Notebook*, *Page-note*, *Search*, *Glossary*, *History*, *Sitemap*, and *Reminder*.

Highlight

The learners can mark any text on the passages just as if they use a highlighter pen to mark their textbooks. When learners revisit the same page, they can see the passages highlighted with a yellow background.

Bookmark

The learner can put a mark on a particular page inside or outside of the Web site of the course, then return to that location from anywhere of the Web site.

Notebook

By using Notebook, learners can take general notes and then read them anywhere in the Web site.

Pagenote

Learners can attach a note to a particular page, then read this note while exploring that page. Unlike Notebook, which allows users to take general notes that can be read anywhere in the Webs site, Pagenote let users add a note only to the current page.

Search

Learners can find information that contains a specific word or a phrase in the followings: course contents, content titles, highlighted passages of text, the keywords that are associated with highlighted text, bookmark titles, notebook titles, notebook contents, pagenotes, or all of the above.

Glossary

Glossary lets learners find definitions of the terms.

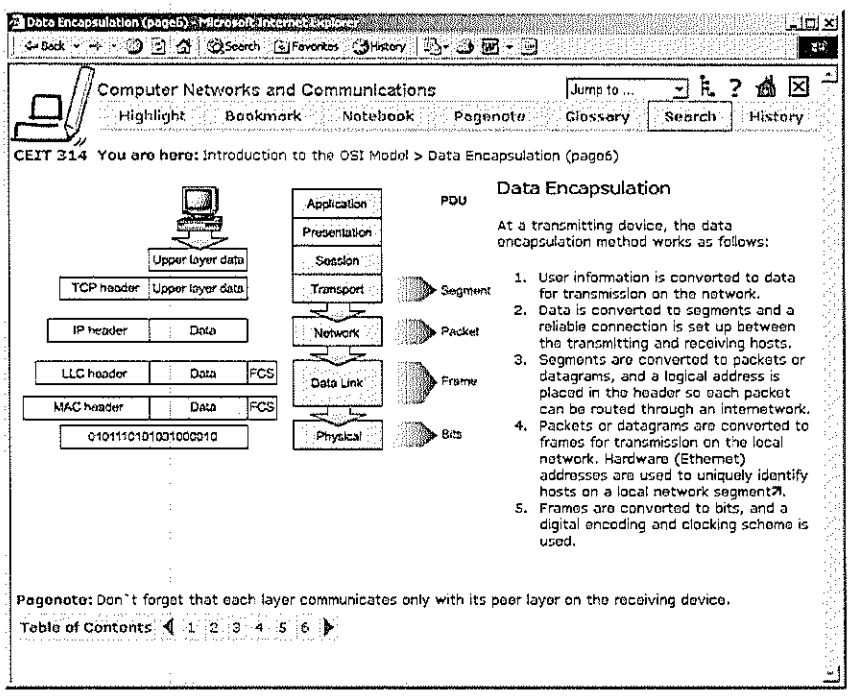

FIGURE 2
The Web Site of the Course

History

History displays the pages visited, the activities done with the tools, or both, in order with the time period selected.

Sitemap

By using *Sitemap*, learners have the chance to see the tree structure of the Web site and access all the pages of the Web site.

Reminder

Learners can post a note to the main page to remind themselves anything when they enter the Web site.

FINDINGS

The analysis of data indicated that factors influencing the learners' use of cognitive tools in the Web-based learning environment fell into four main categories: course, learners, tools, and learning environment, as shown in Figure 3.

Course

Analysis of students' responses indicated that *content complexity* and *evaluation criteria* used in the course were two main contributing factors to students' usage of cognitive tools.

Content Complexity: The students reported that since the course was an introductory one which covered fundamental concepts and definitions of terms, they intended to use the tools for mostly information-seeking and -recalling. For example, one of the students stated that "there are lots of definitions and lots of things to highlight." Another student agreed with this and reported that "if I had begun to use the Highlight tool, there would have been many

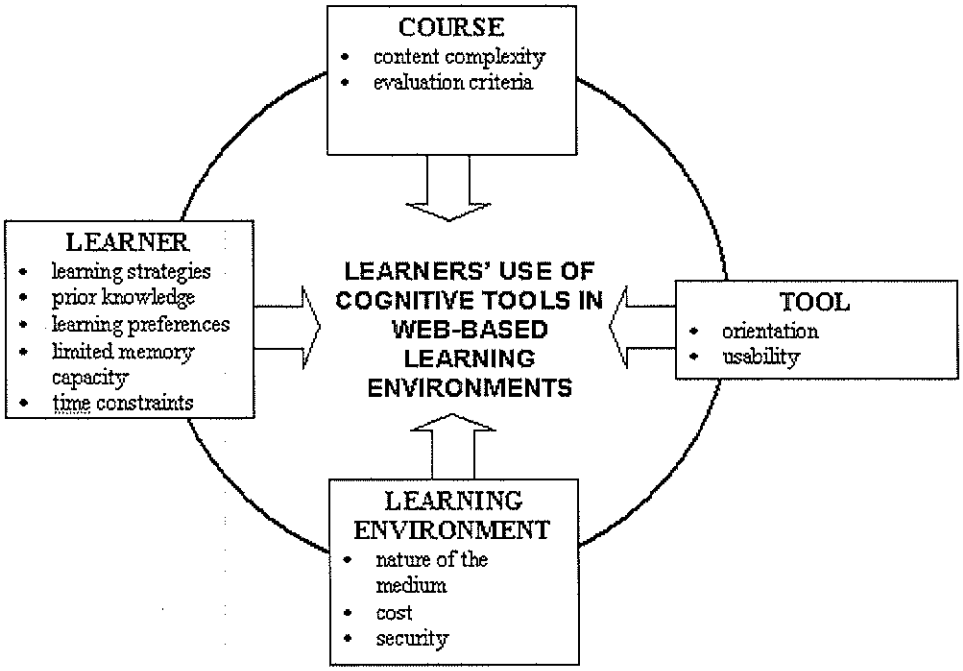

FIGURE 3
Factors Influencing the Use of Cognitive Tools

passages to highlight." These responses clearly indicated that students were to use cognitive tools for more complex content and cognitive tasks, rather than a content that mostly covers facts and definitions.

Evaluation Criteria: Most students believed that if the use of those cognitive tools had been added to their final grades as one of the course requirements, there would have been more use of them. At the same time, a few students stated that "knowing that the instructor is always monitoring for how long we are logged on and how much time we spend on the content" made them anxious and uncomfortable. Thus, it was another factor that affected their use of cognitive tools.

Learner

Students' responses indicated that some factors that influenced their use of cognitive tools resulted from their individual characteristics. Those characteristics included their current learning strategies, prior knowledge, learning preferences, limited memory capacity, and time constraints.

Learning Strategies: At the first class session, students were given a questionnaire on the frequency of their current learning strategies in their regular learning activities. On this scale, items rated on a Likert-type scale of 1 to 5, where 1 represented "least frequently" and 5 represented "most frequently." The results of this questionnaire are presented in Table 1.

The data collected from the questionnaire showed that learning strategies had an influence on their use of cognitive tools. It was obvious from students' statements that they did not change or modify learning styles that they use in traditional learning environments, even though the medium of instruction was totally different.

TABLE 1
Frequency of Students' Usage of Learning Strategies

Learning Strategy	*M*
Use of indexes	3.54
Underlining	3.21
Taking notes on materials	3.11
Taking notes on notebooks	3.11
Highlighting	2.71
Use of glossary	2.71
Use of "post it"	2.64
Book-marking	2.46

On one side of the spectrum, students who use "highlighting" very frequently while reading a printed text did demonstrate the same behavior while reading from a Web site. On the other end of the spectrum, students who were not used to using "highlighting" on printed materials did not feel the necessity of using the same feature while reading from a Web site. Both groups simply backed up their preference, stating that "it's the same for thing for both media."

Prior Knowledge: According to Park and Hannafin (1993) related prior knowledge is the most powerful influence mediating learning. Students indicated that their prior knowledge affected their use of cognitive tools. For instance, one student reported that he used the "Glossary" tool because he wanted to find out what some abbreviations used in the text stood for. Another student, who stated that he had no prior knowledge of the subject, used the "Search" tool access to necessary pages to complete his assignments. One should not overlook the fact that effective acquisition of information depends on the learners' linking new information to their existing knowledge structure (Park & Hannfin, 1993).

Learning Preferences: Some students asserted that they were used to using traditional methods and tools for learning. For example, one student stated that he would prefer taking a note in a notebook, rather than on a screen, so that would be much easier for him to go back to those notes and study without needing a computer. Those responses revealed that students' preferences for learning methods and tools were more in favor of traditional ones, due to their much longer exposure to them.

Limited Memory Capacity: Jih and Reeves (1997) stated that students are required to engage different types of mental effort in interactive learning systems than in print or nonprint media. During the group interviews, students reported that their limited memory capacity was another factor that had them use "bookmarking" and "history" tools. Those students gave two reasons for this. One, they could not keep long and complex Internet addresses in the memory, so they used the "bookmarking" tool. Second, they could not remember what pages or sites they had visited, so they used the "history" tool.

Time Constraints: Finally, students reported that, due to their loaded course schedules and assignments, they did not have enough time to use cognitive tools. For example, some interviewees insisted on the idea that they could hardly arrange themselves to complete the assignments and readings given in any specific week and could not devote enough time to visit the Web site frequently.

Tool

Students advocated that two other factors that influenced their use of cognitive tools resulted from "inadequate orientation" and "tools' usability."

Orientation: Prior research suggests that one of the major factors that affected the use of cognitive tools was the orientation toward the

utilization of the tools (Hill & Hannafin, 1997). The results showed that learners were not provided with enough guidance about the features, usage, and functions of the cognitive tools. For example, one student said, "I realized the Search tool today. I used it for testing.... I checked whether I could find what I looked for when I used it."

Usability: Usability of the cognitive tools also influenced usage of these tools. During the group interview, students mentioned several concerns regarding to the usability of the cognitive tools. Students frequently stated that cognitive tools were supposed to be easy to use. However, those tools, especially the "highlighting" tool, were too complex for students to use.

Learning Environment

Finally, students reported some factors that directly resulted from the learning environment and the medium. Those were "nature of the medium," "cost," and "security."

Nature of the Medium: During the interviews, students reported several concerns with the nature of the Internet and the computer. Those concerns included (1) students' eyes got tired when they looked at the screen for a long period of time (2) unlikelihood of the students to sit in front of a computer for a long time, (3) the slow speed of the Internet connections, (4) frequent unexpected termination of the Internet connections, and (5) the difficulties of having access to computers.

Cost: A considerable number of students stated that cost of Internet services was another factor that prevented them from staying online. Following statement of a student best represents how the internet service costs affected the use of cognitive tools.

> After I read the content once, I get offline and turn back to the contents that are worthwhile. Nevertheless, I can't use the Bookmark tool since I am offline. For this reason, I access the pages from Table of Contents. I don't use the Highlight tool. Instead, I take notes whenever I need to use the Highlight tool.

Security: Students stated that environment security also influenced their selection and use of cognitive tools. Especially, those who thought that their personal information on the Web site would be read or erased by someone else preferred not to use these tools. Another factor that students reported during the group interviews was storage of their personal information by the system. Some students stated that "since all what we record on the web site will be erased at the end of the semester, I rather to keep those on a notebook or a personal computer."

DISCUSSION AND RECOMMENDATIONS

The purpose of this study was to explore the factors influencing the use of cognitive tools in Web-based learning environments. Analysis of data revealed that students used Web-based cognitive tools for a variety of cognitive tasks. Those cognitive tasks and tools used by the students are presented in Table 2.

Cognitive tools have considerable promise in empowering learners in Web-based learning environments (Iiyoshi, 1999). Research studies, concerning factors that affect the use of the tools, patterns, and the effects of cognitive tool use are necessary to come up with more effective cognitive tools. This study provides several implications for the design and use of the cognitive tools for Web-based learning environments. Based on the findings of the study, following recommendations are provided for practitioners of Web-based instruction and Web-based cognitive tool developers.

- Tool orientation sessions should be provided.
- Cognitive tools should be easy to use.
- Instructional activities should demand the use of higher-order thinking.
- Internet connections should be more secure, stable, cheap, and fast.

TABLE 2
Cognitive Tasks and Tools

	Seeking	*Selecting*	*Organizing*	*Integrating*	*Generating*
Highlight	✓	✓	✓		
Bookmark	✓	✓			
Notebook	✓	✓	✓	✓	✓
History	✓	✓			
Sitemap	✓	✓	✓	✓	
Glossary	✓	✓	✓	✓	
Search	✓	✓	✓	✓	
Pagenote		✓	✓	✓	✓
Note to Remember		✓			

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