Applying Cognitive Load Theory to the Design of Web-Based Instruction

Susan Feinberg and Margaret Murphy
Usability Testing and Evaluation Center
Illinois Institute of Technology
3301 S. Dearborn St.
Chicago, IL 60616
feinberg@iit.edu

Cognitive load theory can inform the design of web-based instruction. The basic premise of cognitive load theory is that the focus of an instructional module must be the instruction itself. Information that is adjunct to the instruction must be designed to minimize cognitive load and enhance working memory. Because the mental resources of working memory can be overloaded, any information that ignores cognitive load may interfere with the process of acquiring knowledge and skills. Instruction that effectively presents the learning to our working memory has an impact on our ability to store knowledge and skills in our long-term memory. Everything that we "know" is held in our long-term memory. Our team applied the principles of cognitive load theory to the design our instructional web site and discovered that cognitive load theory provides a sound baseline for the design of effective web-based instruction. Further, to effectively enhance web-based instruction, the graphical user interface and multimedia formats must be developed in consideration of cognitive load principles.

Web-based instruction is in high demand, from both corporations using it for employee training and educational institutions interested in meeting student needs. Currently, to meet the demand for web-based instruction, often course lectures or seminars are video-taped and "dumped" into a shell for an instructional web site. Although the original course presentation may have worked successfully for an on-site audience, the presentation and materials may not be the most effective learning materials for web-based instruction. An interdisciplinary team at the Illinois Institute of Technology applied cognitive load theory to the design of web-based instruction and concluded that not only can design inhibit learning, but a graphical user interface and multi media formats may inhibit learning and impose unnecessary cognitive demand.

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Cognitive load theory is defined as the amount of "mental energy" required to process a given amount of information. As the amount of information increases, so does the cognitive load on our mental resources. When the amount of information and instruction exceed the capacity and limitations of our mental resources, then learning will be inhibited. Sweller and Cooper (1988) described a cognitive modal model of learning that distinguishes between three distinct memory types (modes): sensory memory, working memory and long-term memory.

COGNITIVE MODAL MODEL OF LEARNING

Sensory memory deals with incoming stimuli from our senses, including sights, sounds, smells, tastes and touches. Sensory memories extinguish extremely quickly. *Working memory* (previously named short-term memory) is a three-part system (Baddeley, 1992) that includes a central executive system acting as the attention-controlling system, and two slave systems: the visuospatial sketch pad that manipulates visual images, and the phonological loop that stores and rehearses speech-based information (see Fig. 1). In working memory learning takes place, but working memory has limitations.

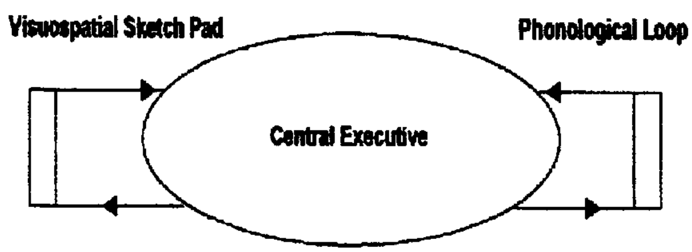

Fig. 1: Baddeley and Hitch Working Memory Model
Source: Baddeley, 1992, pg. 557.

Long-term memory refers to the immense body of knowledge and skills that we hold in a more-or-less permanently accessible form. Everything that we "know" is held in our long-term memory. Unlike working memory, the capacity of long-term memory appears to be unlimited.

What Hinders Learning in Working Memory?

Cognitive load theory distinguishes between two types of instructional information: intrinsic cognitive load and extraneous cognitive load.

Intrinsic cognitive load is related directly to the difficulty of the to-be-learned content (Sweller, Chandler, Tierney and Cooper, 1990). Intrinsic cognitive load is characterized in terms of content that cannot be modified by instructional design. *Extraneous cognitive load* is defined as any cognitive activity engaged in because of the way the task is organized and presented, not because it is essential to attaining relevant goals. Many learning and problem-solving activities impose a heavy extraneous load. We can promote learning by changing the instructional materials presented to students and managing intrinsic and extraneous cognitive load. Conversely, we can have a negative effect on learning by increasing extraneous cognitive load.

HOW CAN LEARNING TECHNIQUES AID IN THE DESIGN OF WEB-BASED INSTRUCTION

A graphical user interface and multimedia formats can increase extraneous cognitive load and have a negative impact on learning. But three learning techniques have direct application in the generation of web-based instruction using multimedia technology. These three include the split-attention effect, the redundancy effect and the modality effect.

Split-Attention Effect. Cognitive load generated by irrelevant activities, such as text and graphics competing, can impede skill acquisition. Instruction that integrates graphics and text was found to be superior to split-sources of information. (Chandler and Sweller, 1991).

Redundancy Effect. Conventional instructional design theory views use of redundant sources as at least neutral and perhaps beneficial in its effect on learning. However, cognitive load theory cautions against the use of simultaneous representations of redundant content in instruction (Chandler and Sweller, 1991). Redundant sources of information place increased demand on cognition that can be freed for intrinsic load. Maps, for example, provide a fully graphic instruction that is completely self-contained.

Modality Effect. Research indicated that more items were recalled in a memory test if some of the items were presented in a visual modality and some in an auditory modality, rather than all in a single modality. This research suggested that more memory capacity was available when dual modalities were used. (Penney, 1989). While dual-modality involves a split-attention effect, it supplies an effectively larger working memory for learners to assimilate instructional material (Chandler 1995). However, if the auditory component is too long or highly complex, it will create excessive demand on working memory. Furthermore, unconstrained use of multimedia (e.g. animation and streaming video) will create excessive demand on working memory.

APPLYING COGNITIVE LOAD THEORY TO THE DESIGN OF WEB-BASED INSTRUCTION

Our interdisciplinary team applied cognitive load theory to the design of our web-based instruction, starting first with the graphical user interface. To minimize extraneous cognition we organized information (e.g. navigation on right), used consistent page layout, and added audio/visual elements for dual modality. Figure 2 illustrates the "shell" for the web site.

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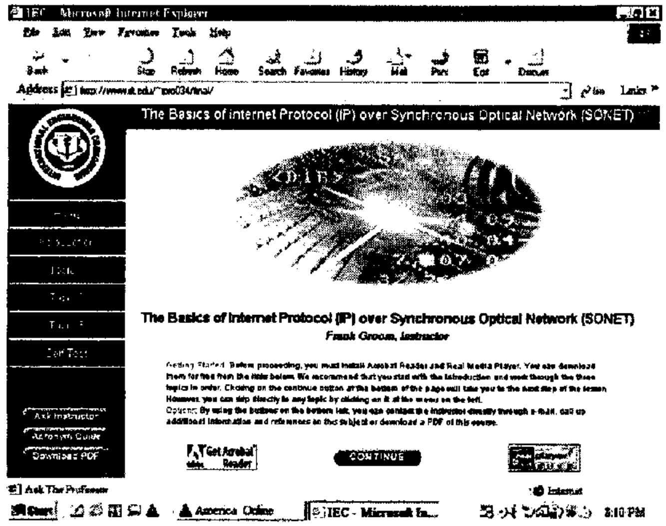

Fig. 2: Graphical User Interface Designed to Minimize Extraneous Cognition

Our next goal was to rewrite the educational instruction (content) using the principles of cognitive load. Our topic was highly complex and technical. Thus, we knew that when instruction is high in intrinsic load (content is highly interactive, complex material), the delivery mode has to maximize working memory by incorporating dual modality. Figure 3 illustrates visuospatial information (text) and the phonological information (the "talking" head).

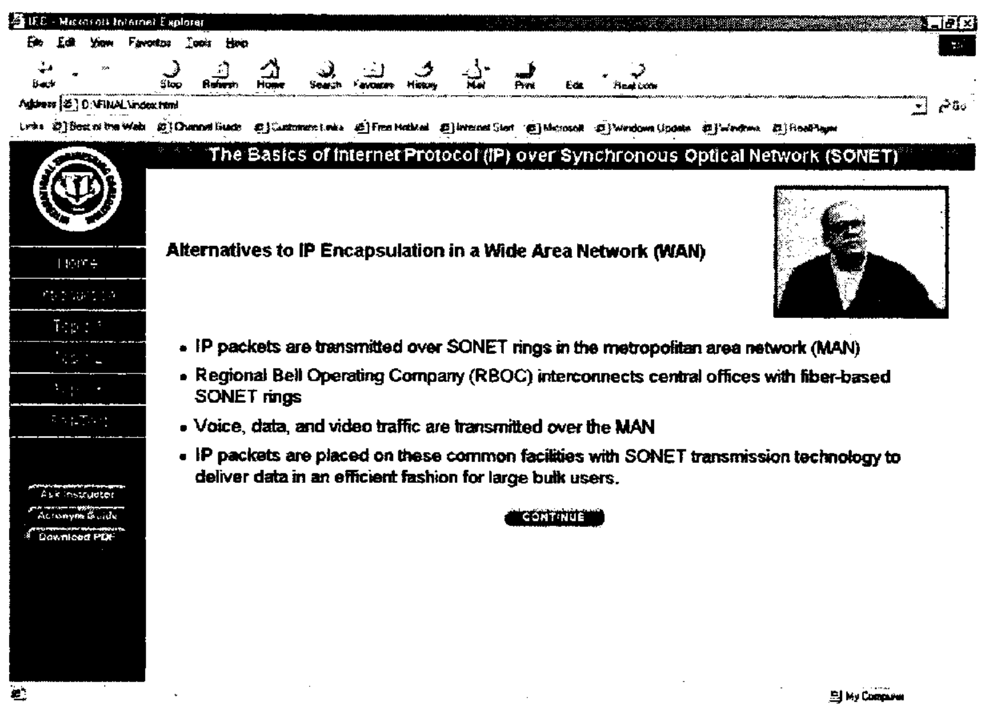

Fig. 3: Interface With Dual Modality to Maximize Working Memory

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We designed integrated text and graphics to accommodate quick reading and visual scanning and to avoid split-attention effect. But, we added background audio information, this time without the visual "talking head," to incorporate dual modality and maximize working memory. We omitted the physical "talking head" because it added additional visual information to an already complex graphic and increased extraneous cognitive load. Figure 4 illustrates the dual modality of integrated text and graphics and audio information.

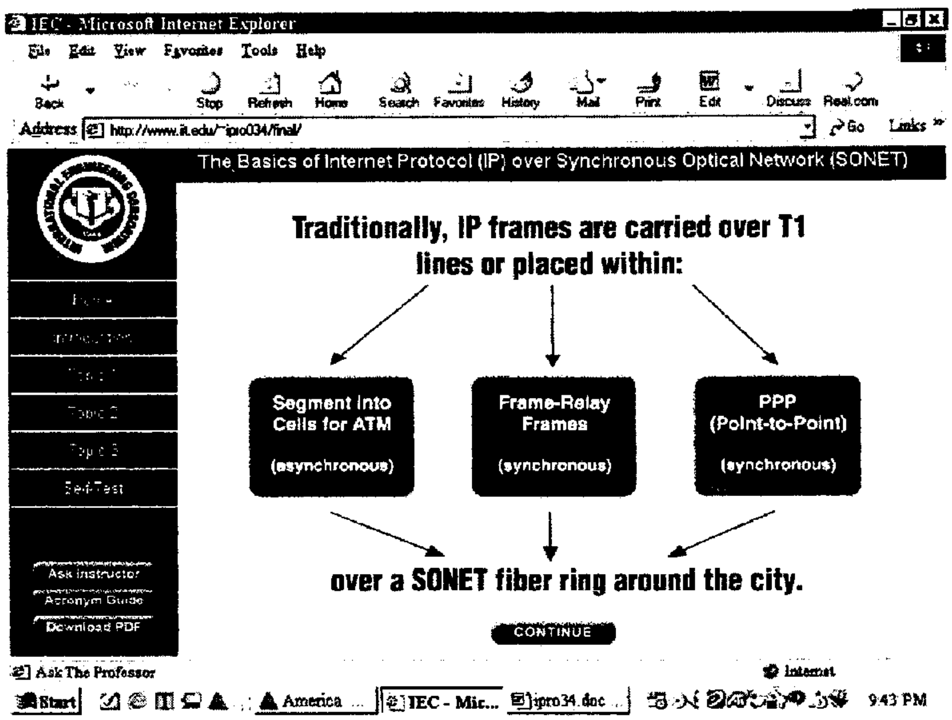

Fig. 4: Integrated Text and Graphics With Background Audio Information

FINDINGS

Finally, we user-tested our multi media instructional web-site. Our four findings for this project indicate that cognitive load theory provides general design principles to reduce extraneous cognitive load caused by the web-based format of the instruction

1. Cognitive load theory provides a sound baseline for the design of effective instruction.
2. The principles of split-attention, redundancy effect and modality effect identified in cognitive load theory have clear applications in the design of web-based instruction.
3. Cognitive load theory is consistent with general web design principles and provides an additional criterion for effective design of web-based instruction.
4. The graphical user interface and multimedia formats must be developed in consideration of cognitive load principles to effectively enhance web-based instruction.

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ABOUT THE AUTHORS

Susan Feinberg is a Fellow of the Society for Technical Communication, a Professor of English and Director of the Usability Testing and Evaluation Center at the Illinois Institute of Technology. The goal of this Center is to promote usability testing as part of the product development cycle, especially for web-based instructional materials. Learning theory as it pertains to web-based and other products is a major focus of the research performed in the Center, research that can contribute to a greater understanding of how people learn.

Margaret M. Murphy is communications coordinator for the Department of Chemical and Environmental Engineering at Illinois Institute of Technology (IIT). She is responsible for image development and communications with all internal and external audiences via print and electronic media. Ms. Murphy is particularly interested in the development of a new paradigm for the design of web-based instruction and has a M.S. in Technical Communications and Information Design from IIT with a concentration in web-based learning theory.