Understanding Cognitive Processes in Educational Hypermedia

Patricia M. Boechler
University of Alberta, Canada

INTRODUCTION

Cognitive load theory (CLT) is currently the most prominent cognitive theory pertaining to instructional design and is referred to in numerous empirical articles in the educational literature (for example, Brünken, Plass, & Leutner, 2003; Chandler & Sweller, 1991; Paas, Tuovinen, Tabbers, & Van Gerven, 2003; Sweller, van Merri¸nboer, & Paas, 1998). CLT was developed to assist educators in designing optimal presentations of information to encourage learning. CLT has also been extended and applied to the design of educational hypermedia and multimedia (Mayer & Moreno, 2003). The theory is built around the idea that the human cognitive architecture has inherent limitations related to capacity, in particular, the limitations of human working memory. As Sweller et al. (pp. 252-253) state:

The implications of working memory limitations on instructional design cannot be overstated. All conscious cognitive activity learners engage in occurs in a structure whose limitations seem to preclude all but the most basic processes. Anything beyond the simplest cognitive activities appear to overwhelm working memory. Prima facie, any instructional design that flouts or merely ignores working memory limitations inevitably is deficient. It is this factor that provides a central claim to cognitive load theory.

In order to understand the full implications of cognitive load theory, an overview of the human memory system is necessary.

BACKGROUND

The Human Memory System: The Modal Model of Memory

It has long been accepted that the human memory system is made up of two storage units: long-term memory and working memory. There is an abundance of behavioral (for example, Deese & Kaufman, 1957; Postmand & Phillips, 1965) and neurological evidence (Milner, Corkin, & Tueber, 1968; Warrington & Shallice, 1969) to support this theory. Long-term memory is a repository for information and knowledge that we have been exposed to repetitively or that has sufficient meaning to us. Long-term memory is a memory store that has an indefinable duration but is not conscious; that is, any information in long-term memory must first be retrieved into working memory for us to be aware of it. Hence, any conscious manipulation of information or intentional thinking can only occur when this information is available to working memory. The depth and duration of processing in working memory determines whether information is passed on to long-term memory. Once knowledge is stored in long-term memory, we can say that enduring learning has occurred.

Working Memory Limitations

Unfortunately, working memory has some very definite limitations. First, there is a limit of volume. Baddeley, Thomson, and Buchanan (1975) reported that the size of working memory is equal to the amount of information that can be verbally rehearsed in approximately 2 seconds. A second limitation of working memory concerns time. When information is attended to and enters working memory, if it is not consciously processed, it will decay in approximately 20 seconds.

CLT AND EDUCATIONAL HYPERMEDIA

The modal model of human memory, specifically these limitations of working memory, is the basis for CLT. A version of CLT, Mayer and Moreno's (2003) selecting-organizing-integrating theory of active learning, is specifically targeted to learning in hypermedia environments. The theory is built upon three core assumptions from the modal model of memory: the dual channel assumption, the limited capacity assumption, and the active processing assumption. The dual channel assumption is based on the notion that working memory has two sensory channels, each responsible for processing different types of input. The auditory or verbal channel processes written and spoken language. The visual channel processes images. The limited capacity assumption applies to these two channels; that is, each of these channels has a limit as to the amount of information that can be processed at one time. The active processing assumption is derived from Wittrock's (1989) generative learning theory and asserts that substantial intentional processing is required for meaningful learning. With these assumptions as a foundation, Mayer and Moreno have focused on three key mental activities that can place demands on available cognitive resources: attention, mental organization, and integration.

Improving Working Memory Capacity Directly

How does CLT advocate improving working memory limitations? To date, the solution for reducing cognitive load has focused on directly reducing the demands on working memory. Mayer and Moreno (2003) outline a number of methods for reducing cognitive load in hypermedia: (a) Resting on the dual channel assumption, cognitive load on one channel can be relieved by spreading information across both modalities, that is, by providing information in both a visual and auditory format, (b) presenting material in segments and providing pretraining on some material can reduce overload, (c) the redundancy of information can be eliminated, and (d) visual and auditory information can be synchronized.

Mayer and Moreno (2003) also refer to "incidental processing" as "cognitive processes that are not required for making sense of the presented material but are primed by the design of the learning task" (p. 45). Incidental processing is considered undesirable as it relates to the cognitive resources that are needed to process extraneous, irrelevant material that may be included on the presentation. Mayer and Moreno advocate weeding out this extraneous material to reduce cognitive load.

Measuring Cognitive Load

If the premise of cognitive load theory is correct, then certainly a primary activity in designing instructional materials must be the meaningful measurement of cognitive load. This is not a simple task as the method of measurement is dependent on the constructs that different researchers use to describe cognitive load. For example, Paas et al. (2003) propose that three constructs define cognitive load: mental load, which reflects the interaction between task and subject characteristics; mental effort, which reflects the actual cognitive reserves that are expended on the task; and performance, which can be defined as the learner's achievements. Previous research in cognitive load measurement has relied on three types of measures to assess the cognitive load of the user: (a) physiological measures such as heart rate and pupillary responses, (b) performance data on primary and secondary tasks, and (c) self-reported ratings (Paas et al.). These tasks have been used in various configurations to measure overall cognitive load (Brünken et al., 2003; Chandler & Sweller, 1996; Gimino, 2002; Paas, 1992). To date, most efforts to measure cognitive load have focused on self-reported ratings (see Paas et al.).

FUTURE TRENDS

Our ability to reduce cognitive load in educational hypermedia rests on our thorough definition of the underlying constructs of cognitive load as well as the

Related Content