Cognitive Load Theory: Intrinsic, Extraneous, and germane Load’s Implications for Instructional Design

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In a publication of the ASTD, a large pull quote – in orange – screamed “50% in 72 pt type, then went on to say “Instruction formatted according to cognitive load theory principles can result in a 50%+ increase in test scores.” (Sweller, 2009, p. 22). 50% is no small increase. So what is Cognitive Load theory? More specifically what are the ‘load’ components of the theory?

This paper is not meant to be a full discussion on Cognitive Load theory but rather an exploration of the Intrinsic, Extraneous, and Germane Load components – the three key dimensions of the theory, and a brief discussion of their implications for Instructional design.

**Overview**

Cognitive Load theory grew out of the area of cognitive psychology. (DeLeeuw & Mayer, 2008) (Baddeley, 1992, p. 556) Focused on how individuals process information in order to move that information from Working Memory to Long-term memory, Sweller postulated that there were three key influencers or ‘loads’ that learning imposed on the process; Intrinsic Load Extraneous Load and Germane Load (Sweller, 1988)

The concept of Working Memory has been around for sometime. (Baddeley, 1992, p. 556). Miller (1956) summarized working memory limitations:

…the span of absolute judgment and the span of immediate memory impose severe limitations on the amount of information that we are able to receive, process, and remember. By organizing the stimulus input simultaneously into several dimensions and successively into a sequence or chunks, we manage to break (or at least stretch) this informational bottleneck.” (1956, pp. Summary, para. 2)

Miller (1956) held that the brain could hold seven plus/minus two bits of new information at a time. He stated:
There is a clear and definite limit to the accuracy with which we can identify absolutely the magnitude of a unidimensional stimulus variable. I would propose to call this limit the span of absolute judgment, and I maintain that for unidimensional judgments this span is usually somewhere in the neighborhood of seven.

Other researchers expanded on this theory with the discussions and research around schema acquisition and their implications for knowledge acquisitions (see figure 1). All told, the research pointed to a need to understand and have a means by which the load put on working memory could be ‘balanced’ in such a way as to increase schemata acquisition and expansion. Rey and Buchwald (2011) pointed out that -

… CLT [Cognitive Load Theory] attached particular importance to both schema construction and automation. A schema is a cognitive construct that organizes the elements of information in order to store them in long-term memory. Schemata serve to allocate mechanisms for the organization of knowledge and their storage. They reduce cognitive load (CL), because a schema is a single entity in working memory but can contain an extensive amount of information.” (Rey & Buchwald, 2011, p. 34)

In 1988 John Sweller stated that “Current theories and practice frequently assume problem solving is an effective means of learning and consequently may require modification” (Sweller, 1988, p. 284). With long-term memory requiring the development or addition of new schema, activities that did not take this into account would fail in the long term. The 1988 study in particular was focused on problem solving and the results cut to the very heart of the current methodology of problem-solving activities as an effective means of teaching, in this case, mathematics.
COGNITIVE LOAD THEORY TIMELINE

Figure 1 Cognitive Load Theory Timeline - Kathy Illian 2010

Sweller pointed out that the heavy cognitive load put on Working Memory was actually detrimental and worked against the goal of long-term memory and capability. True, the students could eventually solve the problems at the time but “Conventional problem solving activity via means-ends analysis normally leads to problem-solution, not to schema acquisition” (1988, p. 283). Additionally Sweller (1988) concluded that “Goal attainment and schema acquisition may be two largely unrelated and even incompatible processes” (p. 283).

The problem with Cognitive Load and schema acquisition was expressed by Richard E. Mayer in 1977. Referring to the process of moving new information bits to long-term memory storage Mayer stated that

the processes of learning as the acquisition of new material in the learner by connecting it (or ‘assimilating’ it to) some aspect of existing cognitive structure (or ‘schema’), and the product of learning as the newly reorganized cognitive structure which integrates old and new knowledge and which, in turn, may serve as an assimilative schema for subsequent
Mayer goes on to quote Barlett (1932, p. 172-201) in saying “without some general setting or label, as we have repeatedly seen, no material can be either assimilated or remembered.” (Mayer, 1977, p. 369)

Sweller and Mayer would over the years come closer to each other in their views of cognitive load and its respective components.

**The Components of Cognitive Load Theory (CLT)**

Over the years Sweller and other researchers refined the model of CLT. (Illian, 2010) Three key load types that defined CLT emerged. Intrinsic Load; Extraneous Load; and in 1998 Germany Load (Merrienboer & Sweller, p 161, 2005)

**Intrinsic Load.** Intrinsic Load is defined by Sweller in 2011 as the “knowledge being acquired. It is content only and has no relationship to any other aspect of how that knowledge is acquired” (2011, p. 57) or what the learner thinks. Intrinsic represents the ‘real world’ of that knowledge or content. Because intrinsic load is ‘real world’ it can become extremely complex. Merrienboer and Sweller point out that this complexity is due to the fact that “as the number of elements that needs to be organized increases linearly, the number of possible combinations increases exponentially” (Merrieboer & Sweller, 2005, p. 156)

An example may help. If I were teaching about Arizona, the number of elements discussed is few and so the possible combinations the learner must process are few. But if I were teaching about the United States the number of elements (50), significantly increases and as a result the number of combinations grows exponentially – far beyond the 50 states themselves. Just in states combinations you have regional combinations, political combinations, geographic combinations, geological combinations, etc. While Arizona would have regional combinations as
well, the elements within its combinations are far fewer.

The rate of the interaction between the elements increases the intrinsic load as well. If I am discussing the United States and comparing and contrasting each state, I have significantly increased the interaction. Sweller uses the example of chemical symbols and the interactions between those symbols to illustrate the same point (Sweller, 2011, p. 58).

**Extraneous Load.** Simply put, extraneous load is how the intrinsic (content) elements are taught or how they present themselves. Unlike intrinsic where the load is a function of the content itself in the real world, extraneous load is under control of the designer/teacher and thus it’s reduction or increase is controllable. (Sweller, 2011, p. 63) Merrienboer and Sweller remind us that the danger inherent in these load types (including germane) is that they are additive. Thus poor design and delivery can increase extraneous load to the point that there is no room for germane and/or intrinsic loads. (Merrieboer & Sweller, 2005, p. 150) Thus even good design can be made moot by poor instruction or vis-a-versa.

This additive nature also implies that if the intrinsic load is not controlled the same overload could occur and failure to learn result.

**Germane Load.** Germane load is the load imposed by the learner as they seek to understand and make connections to schema they already possess in long-term memory. DeLeeuw and Mayer (2008) also indicate that motivation plays a key role in Germane load. Another way to look at it is ‘So What’. What’s in it for me? Without a desire to find linkage to past understanding or build new understanding the germane load is becomes a non-starter. (DeLeeuw & Mayer, 2008, p. 1).

Activity is often put forward as an example of the learner’s involvement in the learning process. Examples of this emphasis are found in the number of simulations, games, and related
activities promoted to organizations as the next best thing for learning. But not all activity is equal. Mayer (2005) points to two types of activity: behavior, and cognitive. If the learning approach creates cognitive activity then the learner is making the connections needed to create long-term schema’s. Behavior activity is more apparent through physical movement – clicking a button or building an object (p. 14). And while there may in fact be an increase in the germane load on the learner - an involvement of an information processing nature - it doesn’t mean that it is creating the necessary schema that will impact long-term learning (Clark & Mayer, 2008, p. 5) (Mayer, 2005, p. 14). Specifically Clark and Mayer state that “physical activity does not equate to mental activity, and it is mental, not behavioral activity that leads to learning” (2008, p. 5).

The three load conditions that Sweller (1988) proposes are also found in Mayer’s Cognitive Theory of Multimedia Learning. Initially labeled differently and difficult to draw comparisons to, Mayer has evolved the cognitive learning aspect of his theory and his comparable components are illustrated below. While not exactly the same, they are similar enough that it is important that the instructional designer familiarize themselves with both theories. This has become particularly important in this age of media. With PowerPoint used in nearly every type of presentation or training setting Mayer’s CTML is specifically relevant (DeLeeuw & Mayer, 2008, p. 223).
Implications for Design.

Designers have often lead with a traditional approach in their design; traditional because that is the way it has been done in the past. Often this is the result of SME’s without formal training being moved into a ‘designer’ role. What they know is what has worked well for them. While on the surface this seems reasonable (it worked in the past, right?) the danger lies in the nature of the training environment itself. The learners change, the content changes, the desired outcomes change. Yet if the training approach remains the same or at least similar it will be rare that it is as successful as it should be.

Take the United States example. If the training had been originally written for 8th graders, the 8th graders bring a very robust schema of the overall framework of the US. This allows Working Memory to coast a little. It can access long-term memory schema that new concepts easily attach to. It may be a challenge but it is reasonable and well connected. If the lesson was poorly designed or taught the learner would not suffer too greatly due to the low intrinsic load. The Extraneous load would be high but the low intrinsic load would be make up the difference.
But if the same lesson was taught to 1st graders in the same way, the learners would walk away confused with very little learning having taken place. With a low level of available of schemas to draw from, the intrinsic load would be exceptionally high. The high extraneous load brought on by poor design and presentation would compound this high level.

Additional research in the area of Cognitive Load has uncovered several additional effects of these cognitive load components – 13 in all (Sweller, 2011, p. 69). While it is not within the scope of this paper, it should be noted that the Instructional Designer should make themselves familiar with them and their implications. We will touch on one effect as an example of their importance: Expertise Reversal.

Expertise Reversal as described by Merrienboer & Sweller (2005) “is demonstrated when instructional methods that work well for novice learners have no effects or even adverse effects when learners acquire more expertise.” The general consensus being that this is the result of drop in germane load as a result of the integration of new content into existing schema – a drop in intrinsic load. (p. 163)

Failure to take into account the types of cognitive loads and/or their effects is to turn down a significant level of predictability. Clark and Mayer (2005) state it well when they said “we favor evidence-based practice – the idea that instructional techniques should be based on research findings and research – based theory”(Clark & Mayer, 2008, p. 50).
References


