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## Cognitive Load Theory and the Role of Learner Experience: An Abbreviated Review for Educational Practitioners

ANTHONY R. ARTINO, JR.

*University of Connecticut, USA*  
tony\_artino@yahoo.com

The purpose of this review is to provide educational practitioners with a brief overview of cognitive load theory (CLT) and its major implications for learning. To achieve this objective, the article includes a short description of human cognitive architecture as conceived by cognitive load theorists. Following this overview, the article provides a description of what makes CLT different from other cognitive theories. Included in this section is a summary of the predictions about learning and novel instructional designs that CLT has produced. Next, the article presents a discussion of learner experience and how different levels of prior knowledge can interact with various instructional methods to differentially influence learning outcomes. Finally, the review ends with a discussion of various instructional methods that may be problematic when considered from a CLT perspective. With an understanding of CLT and its instructional implications, educational practitioners will be in better position to design and develop instructional materials that align with human cognitive architecture. Ultimately, instructional materials that utilize CLT guidelines have the potential to enhance learning effectiveness and efficiency for students in a multitude of education and training contexts.

As part of a larger class of limited capacity theories (Goldman, 1991), cognitive load theory (CLT) provides a framework for designing instructional materials. The basic premise of CLT is that learners have a working memory with very limited capacity when dealing with new information (Sweller, van Merriënboer, & Paas, 1998). Moreover, CLT assumes that learners have “an effectively unlimited long-term memory holding cognitive schemas that vary in their degree of complexity and automation” (van Merriënboer & Ayres, 2005, p. 6). The implication of these assumptions is that learning will be hindered if instructional materials overwhelm a learner’s limited working memory resources. Accordingly, early CLT research focused on identifying instructional designs that can effectively reduce unnecessary cognitive burden on working memory, thereby supporting improved learning efficiency (van Merriënboer & Sweller, 2005). More recently, cognitive load theorists have shifted their attention to how learner characteristics, such as prior knowledge and motivational beliefs, interact with instructional designs to influence the effectiveness of CLT methods (Moreno, 2006).

The purpose of this review is to provide educational practitioners with a brief overview of CLT and its major implications for learning. To achieve this objective, the article includes a short description of human cognitive architecture as conceived by cognitive load theorists. Following this overview, the article provides a description of what makes CLT different from other cognitive theories. Included in this section is a summary of the predictions about learning and novel instructional designs that CLT has produced. Next, the article presents a discussion of learner experience and how different levels of prior knowledge can interact with various instructional methods to differentially influence learning outcomes. Finally, the review ends with a discussion of various instructional methods that may be problematic when considered from a CLT perspective.

## COMPONENTS OF HUMAN COGNITIVE ARCHITECTURE

### Working Memory

According to Sweller et al. (1998), humans are only conscious of the information currently being held and processed in working memory and are essentially oblivious to the enormous amount of information stored in long-term memory. Furthermore, when handling new information, working memory is severely limited in both capacity and duration; that is, working

memory can only hold about seven (plus or minus two) items, or chunks of information, at a time (Miller, 1956). Additionally, when *processing* information (i.e., organizing, contrasting, and comparing), rather than just storing it, humans are probably only able to manage two or three items of information simultaneously, depending on the type of processing required (Kirschner, Sweller, & Clark, 2006). Finally, new information held in working memory, if not rehearsed, is lost within about 15 to 30 seconds (Driscoll, 2005).

Another important characteristic of working memory is that its capacity is distributed over two, partially independent processors (Sweller et al., 1998). This dual-processing assumption is based, in part, on Pavis's (1986) dual-coding theory and Baddeley's (1998) theory of working memory, both of which suggest that there are two separate channels for processing visual and auditory information. The implication of this dual-processing model is that limited working memory capacity can be effectively expanded by utilizing both visual and auditory channels rather than either processing channel alone (Sweller et al., 1998). Known as the *modality effect* (Mousavi, Low, & Sweller, 1995), this result has important implications for instructional designers (see discussion regarding CLT predictions).<sup>1</sup>

### Long-Term Memory, Schema Construction, and Schema Automation

Unlike working memory, the capacity of long-term memory is essentially limitless. Furthermore, information held in long-term memory is organized and stored in the form of domain-specific knowledge structures known as schemas (van Merriënboer & Ayres, 2005). Schemas categorize elements of information according to how they will be used, thereby facilitating schema accessibility later when they are needed for related tasks (Sweller et al., 1998). Thus, from the CLT perspective, "human expertise comes from knowledge stored in these schemata, *not* from an ability to engage in reasoning with many elements that have not been organized in long-term memory" (van Merriënboer & Sweller, 2005, p. 149).

As indicated by Sweller (2004), the relationship between working memory and schemas stored in long-term memory may be even more important than the processing limitations of working memory. This is because schemas do more than just organize and store information; they also effectively augment

working memory capacity. Although working memory can hold only a limited *number* of items at a time, the size and complexity of those elements are unlimited (Sweller et al., 1998). Therefore, complex schemas consisting of huge arrays of interrelated elements can be held in working memory as a single entity. As a result, a student dealing with previously learned material that has been stored in long-term memory is, in effect, freed from the processing limitations of working memory—limitations that only apply to novel materials that have no associated schemas (Kirschner et al., 2006). In sum, schemas serve two functions in CLT: the organization and storage of information in long-term memory and the expansion of working memory capacity (Sweller et al., 1998).

Automation is another critical component of schema construction. Automation occurs when information stored in schemas can be processed automatically and without conscious effort, thereby freeing up working memory resources. Constructed schemas become automated after extensive practice, and existing schemas will vary in their degree of automation (van Merriënboer & Sweller, 2005). As Sweller et al. (1998) described, “with automation, familiar tasks are performed accurately and fluidly, whereas unfamiliar tasks—that partially require the automated processes—can be learned with maximum efficiency because maximum working memory capacity is available” (p. 258). On the other hand, without schema automation, a previously encountered task might be completed, but the process will likely be slow and awkward. Furthermore, consistent with CLT, entirely new tasks may be impossible to complete until prerequisite skills have been automated because there simply may not be enough working memory capacity available for learning (van Merriënboer & Sweller, 2005). Ultimately, in view of these theoretical assumptions, schema construction and automation become the major goals for instructional systems that are developed from a cognitive load perspective (Sweller et al.).

## DIFFERENT TYPES OF COGNITIVE LOAD

Although schemas are stored in long-term memory, their construction occurs in working memory. Specifically, when learning new material, students must attend to and manipulate relevant pieces of information in working memory before it can be stored in long-term memory (Sweller et al., 1998). Consequently, of primary importance to cognitive load theorists is the ease with

which information can be processed in working memory; that is, the *cognitive load* imposed on working memory. According to CLT, three different types of cognitive load can be distinguished:

1. *Intrinsic cognitive load*—refers to the number of elements that must be processed simultaneously in working memory for schema construction (i.e., *element interactivity*). Element interactivity is dependent on both the complexity of the to-be-learned material and the learners' expertise (i.e., their schema availability and automaticity; Gerjets & Scheiter, 2003). Stated another way, "intrinsic cognitive load through element interactivity is determined by an interaction between the nature of the material being learned and the expertise of the learners" (Sweller et al., 1998, p. 262).
2. *Extraneous cognitive load*—also known as ineffective cognitive load—is the result of instructional techniques that require learners to engage in working memory activities that are not directly related to schema construction or automation (Sweller, 1994). Much of the early research in CLT revealed that many commonly used instructional designs require learners to use cognitive resources that are not related to, or helpful for, learning (e.g., searching for information that is needed to complete a learning task). Furthermore, because intrinsic cognitive load due to element interactivity and extraneous cognitive load due to instructional design are additive (Sweller et al., 1998), the end result may be fewer cognitive resources left in working memory to devote to schema construction and automation during learning. Consequently, learning may suffer (Sweller, 1994).
3. *Germane cognitive load*—also known as effective cognitive load—is the result of beneficial cognitive processes such as abstractions and elaborations that are promoted by the instructional presentation (Gerjets & Scheiter, 2003). When intrinsic and extraneous cognitive load leave sufficient working memory resources, learners may "invest extra effort in processes that are directly relevant to learning, such as schema construction. These processes also increase cognitive load, but it is germane cognitive load that contributes to, rather than interferes with, learning" (Sweller et al., 1998, p. 264).

In summary, based on the cognitive demands imposed on working memory from the three sources of cognitive load, CLT suggests that instructional

designers should focus on two tasks: (a) reduce extraneous cognitive load, and (b) encourage learners to apply available resources to advanced cognitive processes that are associated with germane cognitive load (Gerjets & Scheiter, 2003).

### UNIQUE CONTRIBUTIONS: LEARNING PREDICTIONS AND NOVEL INSTRUCTIONAL DESIGNS

Cognitive load theory suggests that learning happens best when instructional materials align with human cognitive architecture (Sweller et al., 1998). Thus, “by simultaneously considering the structure of information and the cognitive architecture that allows learners to process that information, cognitive load theorists have been able to generate a unique variety of new and sometimes counterintuitive instructional designs and procedures” (Paas, Renkle, & Sweller, 2003, p. 1). In many ways, this focus on information *and* cognitive structures—as well as the ultimate goal of generating new and efficient instructional techniques (Sweller & Chandler, 1991)—has distinguished CLT from many other cognitive theories. This is not to say that all other theories have failed to consider the interaction between external instructional presentation and internal cognitive structures and function. Certainly Gagne’s theory, among others, was sensitive to the idea that if learning is to occur, instructors must deliberately arrange the external and internal *conditions of learning* (Gagne, Wager, Golas, & Keller, 2005). However, it seems that more than any other,<sup>2</sup> CLT has focused on understanding this interaction from a theoretical perspective and then has applied that understanding to the development of instructional methods. In particular, over the last 30 years, cognitive load theorists have systematically developed hypotheses, generated and tested novel instructional methods based on those hypotheses, and modified their original theory as necessary to account for unexpected findings (Dixon, 1991). This underlying CLT approach is exemplified in a statement from Sweller and Chandler (1991) in reply to critiques by Dixon (1991) and Goldman (1991): “a theory of cognition and instruction that does not lead to novel instructional procedures is a deficient theory. Our field is an applied field and that means theory application” (p. 358).

As a result of their focus on theory application, CLT has made many predictions regarding how people learn, and those predictions have led to

numerous instructional design techniques aimed at keeping extraneous cognitive load as low as possible during learning. Table 1 includes a summary of the learning effects that have emerged from this initial emphasis on reducing extraneous cognitive load. Instructional designers and teachers striving to design learning environments that align with human cognitive architecture should review these CLT effects and consider their application to both classroom and computer-based learning situations. For example, in an attempt to reduce extraneous cognitive load, an instructional designer might place additional explanatory information in narration instead of adding it to an already complex visual display. In doing so, the instructional designer effectively reduces extraneous cognitive load by helping the student “off-load” some essential processing from the visual channel to the auditory channel (Smith & Ragan, 2005). In a similar fashion, a teacher can reduce extraneous cognitive load by providing students with pretraining; that is, providing instruction on prerequisite knowledge prior to asking students to use that new knowledge in the context of a more complex application.

More recently, CLT researchers have recognized that simply freeing working memory capacity by reducing extraneous load may not be a sufficient condition for instruction to be effective (Paas, Renkl, & Sweller, 2004). Accordingly, investigators have begun studying other techniques meant to *optimize* cognitive load; that is, methods designed to decrease intrinsic load and bolster germane load (Paas et al., 2003).

#### THE ROLE OF EXPERIENCE AND LEARNING: THE EXPERTISE REVERSAL EFFECT

As interest in optimizing cognitive load has increased, so too has a more dynamic approach to CLT (Kalyuga & Sweller, 2004, 2005). This dynamic approach recognizes that the effectiveness of an instructional design depends, in part, on the learner’s experience in the domain being taught (Kalyuga, Ayres, Chandler, & Sweller, 2003).

**Table 1**

Some Cognitive Load Theory Effects and How They Reduce Extraneous Cognitive Load (adapted from Sweller et al., 1998)

CLT Effect	Instructional Description	Extraneous Load
Goal-free effect	Replace conventional problems with goal-free problems that provide learners with a non-specific goal	Reduces extraneous load caused by relating a current problem state to a goal state and attempting to reduce the difference between them
Worked example effect	Replace conventional problems with worked examples that must be carefully studied	Reduces extraneous load caused by weak-method problem solving
Completion problem effect	Replace conventional problems with completion problems, providing a partial solution that must be completed by the learner	Reduces extraneous load because giving part of the solution reduces the size of the problem space
Split attention effect	Replace multiple sources of information (i.e., separate pictures and text) with a single, integrated source of information	Reduces extraneous load because there is no need to mentally integrate the information sources
Modality effect	Replace a written explanatory text and another source of visual information (e.g., a diagram) with a spoken explanatory text and a visual source of information (i.e., use multiple modalities)	Reduces extraneous load because multimodal presentation uses both the visual and auditory processors of working memory
Redundancy effect	Replace multiple sources of information that are self-contained (i.e., they can be understood on their own) with one source of information	Reduces extraneous load caused by unnecessary processing of redundant information

Because novices lack the schemas necessary to process complex material in working memory, instructional guidance can act as a surrogate for these missing schemas, thereby promoting schema construction (Sweller et al., 1998). Without instructional guidance, novices quickly succumb to heavy cognitive load, and very inefficient learning, if any at all, will occur. In contrast, more experienced learners are able to activate relevant schemas and, as such, may not require additional instructional guidance. If, nevertheless, instructional guidance is provided to more experienced learners, and they are unable to avoid attending to this information, “there will be an overlap between scheme-based and the redundant instruction-based components of guidance” (Kalyuga et al., 2003, p. 24). As a result of this redundancy, more experienced learners may face cognitive overload as additional

working memory resources are consumed trying to deal with the same information. For more experienced learners, then, it may be preferable to eliminate the instruction-based guidance, thereby reducing cognitive load and improving learning efficiency. Considering these mechanisms, it becomes apparent that instructional techniques that are highly effective for novices can lose their effectiveness, and can even have negative consequences for learning, when used with more experienced learners. This idea is known as the *expertise reversal effect* (Kalyuga et al.).

The expertise reversal effect is a clear example of an aptitude-treatment interaction (Cronbach & Snow, 1977), and numerous studies have provided evidence that this effect generalizes across a wide range of learners and instructional methods (Kalyuga et al., 2003; Kalyuga, Chandler, & Sweller, 2000). The instructional design implication of the expertise reversal effect is conceptually straightforward but can be technically difficult to implement; simply stated, effective instructional materials must be tailored to the learner's level of expertise (Kalyuga & Sweller, 2004, 2005). In traditional classrooms, this type of instructional tailoring is often referred to as adaptive scaffolding; that is, supporting novice learners by limiting the complexities of the learning context and then gradually removing those limits as learners construct knowledge and gain expertise (Driscoll, 2005). In computer-based environments, however, this type of instructional tailoring becomes very complex, from a technical standpoint, and requires that the computer be capable of dynamically assessing the expertise of the individual learner and then adapting instruction, in real-time, to changes in the student's performance and cognitive load (van Merriënboer & Sweller, 2005). Although difficult to implement in computer-based applications, this type of dynamic assessment of learner expertise is currently being researched by CLT theorists and will likely become a reality in the not-too-distant future (Kalyuga, 2006; Kalyuga & Sweller, 2005).

## POTENTIALLY PROBLEMATIC INSTRUCTIONAL METHODS

Current views of learning and instruction tend to focus on the use of minimally-guided, authentic tasks to enhance student learning and motivation (Reigeluth, 1999; van Merriënboer, Kirschner, & Kester, 2003). These approaches, which include discovery learning (Bruner, 1961), anchored instruction (Cognition and Technology Group at Vanderbilt, 1997), problem-based learning (Evenson & Hmelo, 2000), and constructivist learning

(Jonassen, 1999), to name just a few, all assume that such pedagogical techniques help learners integrate the knowledge, attitudes, and behaviors necessary for effective performance; enhance student motivation by providing an authentic context for learning; and, ultimately, enable students to transfer what is learned to novel problems encountered elsewhere (Kirschner et al., 2006). However, when considered from a CLT perspective, all of these approaches suffer from at least one significant flaw; specifically, that the working memory resources of learners, particularly novices, can quickly become overwhelmed by task complexity and, as a result, learning will suffer (for a more complete review of the problems associated with minimally-guided instruction, see Kirschner et al., 2006; Mayer, 2004).

As far as cognitive load theorists are concerned, the answer to inefficient, minimally-guided instruction is direct guidance and scaffolding. For instance, Kirschner et al. (2006) argued, “In so far as there is any evidence from controlled studies, it almost uniformly supports direct, strong instructional guidance rather than constructivist-based minimal guidance during the instruction of novice to intermediate learners” (p. 83). An example of such instructional guidance has been developed by Pollock, Chandler, and Sweller (2002), in an effort to manage intrinsic cognitive load when teaching complex material. Specifically, the researchers developed an instructional technique that artificially reduces element interactivity in to-be-learned material such that novices can circumvent working memory limitations and begin developing partial, rudimentary schemas. This technique, known as the “isolated elements” procedure, is used in the first phase of a training program and is followed by an “interacting elements” phase, which is characterized by the inclusion of all elements necessary for understanding. In a series of experiments, Pollock et al. found that a mixed instructional design (isolated elements followed by interacting elements instruction) was superior to a conventional method (interacting elements used in both stages of instruction) for novice trade school students.

Another classic example of the benefits of instructional guidance, as opposed to pure discovery learning, is Palincsar and Brown’s (1984) groundbreaking work on reciprocal teaching. In this instructional method—often thought of as a constructivist teaching practice—students work together in small groups and take turns leading a discussion of segments of text. The ultimate goal of this teaching method is to encourage students to work collaboratively and to help each other understand and think deeply about what they read (Palincsar, 2003). However, when done correctly,

students are not left alone in this task; instead, research has shown that “some amount of teacher guidance is needed to keep discussions focused on targeted cognitive skills” (Mayer, 2004, p. 17). Thus, consistent with the CLT perspective, reciprocal teaching methods highlight the need to provide students with guidance and scaffolding in order to maintain student focus and avoid cognitive overload during a task that has the potential to become overwhelming in its complexity.

More recently, a number of CLT researchers (Gerjets & Scheiter, 2003; Moreno, 2005, 2006; Paas, Tuovinen, van Merriënboer, & Darabi, 2005) have challenged others in the field to broaden their conceptions of what it means to create an effective and efficient learning environment, and to begin considering the motivational effects of constructivist-based methods. For instance, Moreno (2005, 2006) has proposed an expanded view of CLT that includes self-regulation and motivation factors as learning mediators. According to her cognitive-affective theory of learning with media, “some media may be perceived as more interesting than others, therefore producing positive learning benefits by influencing students to spend more effort on the task” (Moreno, 2006, p. 178). Similarly, students may perceive some instructional methods as more supportive than others, therefore producing positive learning results by minimizing anxiety and bolstering students’ confidence in their ability to successfully complete the learning task (i.e., increasing students’ self-efficacy for learning; Moreno, 2006). Ultimately, for CLT to become an even more relevant theory of learning and instruction, “cognitive load researchers need to determine the motivational effects of instructional conditions...as well as assist instructional designers to recognize the power of authentic learning environments in enhancing the motivation of learners” (Paas et al., 2005, p. 27).

## SUMMARY

The purpose of this article was to provide an overview of CLT and its major pedagogical implications. The article included a short description of human cognitive architecture and a description of what makes CLT different from other cognitive theories; namely, its focus on theory application. Additionally, the article presented a discussion of the expertise reversal effect; the CLT notion that the effectiveness of certain instructional techniques depends, in part, on the learner’s experience. Finally, the review ended with a discussion

of various instructional methods that may be problematic when considered from a CLT perspective.

With an understanding of CLT and its instructional implications, educational practitioners will be in better position to design and develop instructional materials that align with human cognitive architecture. Ultimately, instructional materials that utilize CLT guidelines have the potential to enhance learning effectiveness and efficiency for students in a multitude of education and training contexts.

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#### Notes

1. The modality effect is not limited to CLT; it has been confirmed by numerous researchers from a variety of theoretical perspectives (e.g., Mayer, 2001; Mayer & Moreno, 2003; Penny, 1989; Reed, 2006).
2. Mayer's (2001) cognitive theory of multimedia learning (CTML) also has focused on theory application, and the result has been numerous instructional recommendations based on CTML. However, Mayer's CTML adopted many of the assumptions of CLT and, as a result, his theory is *closely* related to CLT (see discussion in Reed, 2006).