Cognitive Load Theory:
Instruction-based Research with Applications for Designing Tests

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Cognitive load theory (CLT) can be defined as a theory of learning and instructional design principles based on assumptions about human cognitive architecture (Sweller, 2004; van Merriënboer & Ayres, 2005). Since the 1980s, educational researchers have applied CLT in their theoretical and empirical work on issues such as transfer of learning, memory, instructional design, and measurement of cognitive load (Clark, Nguyen, & Sweller, 2006). As a result, researchers have established evidence-based guidelines for classroom instruction (Clark et al., 2006) and multimedia instruction (Mayer & Moreno, 2003).

CLT is based on an information-processing framework that holds direct implications for instruction and related activities where learners interact with written material and visuals. In recent years, CLT research has gained in prominence, as evidenced by four special issues of peer-reviewed journals devoted entirely to the theory (*Educational Technology, Research, and Development*, 2005, *53*[3]; *Educational Psychologist*, 2003, *38*[1]; *Instructional Science*, 2004, *32*[1-2]; *Learning and Instruction,* 2002, *12*[1]). Some current research enterprises in CLT are focused on (a) the advancement of cognitive load measures (e.g., Brünken et al., 2003), (b) the role of expertise in instructional design, and the measurement of expertise (Rikers, van Gerven, & Schmidt, 2004; van Gog, Ericsson, Rikers, & Paas, 2005); (c) the effect of mental rehearsal on learning (Cooper, Tindall-Ford, Chandler, & Sweller, 2001); (d) multimedia learning (Moreno & Valdez, 2005); and (e) the biological evolution of the human cognitive architecture (Sweller, 2004, 2008).

We believe CLT has some useful applications to the design of tests that can result in more accessible tests for all students. Some of the measurement tactics that have grown out of the research on CLT also are useful for documenting the effects of changes in cognitive demand required by test items. In this paper, we (a) examine the development of CLT and key research where it has been applied; (b) discuss major assumptions and terminology of CLT; and (c) conclude with a discussion of the applications of CLT to the development of highly accessible tests.

Brief History of CLT

CLT originated in the 1980s through the work of John Sweller and his colleagues at the University of New South Wales (Clark, et al., 2006; Paas, Renkl, & Sweller, 2003). Like many other educational researchers at the time, Sweller and his team were interested in a cognitive approach to problem solving. Their research built on decades of prior research in the field of educational and cognitive psychology.

Sweller specifically acknowledged the publication of Newell and Simon's (1972) book on problem solving as foundational to his initial research (Clark et al., 2006). Sweller and his colleagues further drew from Miller's (1956) paper on the processing limitations of working memory, as they began to consider the effect of instructional design on the transfer of problem-solving skills (Clark et al., 2006). By the mid-80s, Sweller and his team recognized that instruction via worked examples produced superior test outcomes compared to practice-only instruction. Drawing from Miller's work, they attributed this effect to a reduction of cognitive load in the students' working memory (Cooper & Sweller, 1987; Sweller & Cooper, 1985). The empirical verification of this "worked example effect" via reduced cognitive load, however, was not provided until the early 1990s using self-report measures of mental effort (Pass, 1992; Pass & van Merriënboer, 1994)

After the introduction of the worked example effect, Sweller and a number of other researchers began to examine the structure of worked examples, which led to the discovery of additional learning effects such as the "split-attention effect" (e.g., Tarmizi & Sweller, 1988), the "redundancy effect" (e.g., Chandler & Sweller, 1991), and the "modality effect" (e.g., Mousavi, Low, & Sweller, 1995). Following these research findings, Sweller and Chandler (1994) discovered that these effects were contingent on content complexity. That is, the discovered effects were readily obtainable for complex content, but could not be replicated for content featuring only one or two elements. In subsequent work, Sweller and colleagues conceptualized content complexity as "element interactivity" and defined it as the extent to which multiple content components must be processed simultaneously in working memory to allow for problem solving (Clark et al., 2006; Paas et al., 2003). Sweller and his colleagues worked on integrating the concept of element interactivity into CLT, which led to the concept of ***intrinsic load*** as an additional type of cognitive load (Clark et al., 2006). Up until then, CLT researchers were concerned with the reduction of ***extraneous load*** via improved instructional design (e.g., avoiding split-attention and redundancy). With the introduction of intrinsic load—the latter being determined by the complexity of the material (i.e., element interactivity)—CLT researchers began to consider the additive nature of cognitive load: high extraneous load in addition to high intrinsic load leads to ***cognitive overload***, whereas high extraneous load in addition to low intrinsic load does not (Clark et al., 2006). The failure to demonstrate CLT effects (i.e., improved learning outcomes following the reduction of extraneous load) for less complex material thus could be explained: "If intrinsic cognitive load was low due to low element interactivity, it hardly mattered what the instructor did because memory was not overloaded" (Clark et al., 2006, p. 312).

In 1994, Paas and van Merriënboer introduced a third type of cognitive load they called ***germane load***. Germane load accounts for an increase in cognitive load due to content variability, which can promote the generalization of learning (Clark et al., 2006). Germane load therefore enhances learning by facilitating schema acquisition and automation, whereas extraneous load interferes with learning due to poor instructional design (Mayer, 2008; Paas et al., 2003). Paas (1992) and Paas and van Merriënboer (1994) further advanced CLT by introducing self-report measures of ***mental effort.*** Up until then, Sweller and his colleagues attributed the efficacy of their instructional techniques to a reduction of cognitive load without direct empirical support. That is, the superior learning outcomes of CLT-based instruction versus traditional instruction were used to make inferences about human cognitive architecture. The same data, however, could have been used to infer alternative explanations. The type of self-report measure used by Paas and van Merriënboer allowed CLT researchers to provide evidence that their instructional techniques not only promoted efficient learning, but also reduced the experienced mental effort of the task (Clark et al., 2006). The use of self-report measures were quickly adopted by CLT researchers around the world, and the work by Paas and van Merriënboer further initiated research on the measurement of cognitive load (Brünken, Plass, & Leutner, 2003; Paas, Tuovinen, Tabbers, & van Gerven, 2003).

Major Assumptions and Types of Cognitive Load

Assumptions in Cognitive Load Theory

CLT researchers are primarily concerned with instructional techniques for managing working memory load to facilitate learning (Paas et al., 2003). Learning is hereby defined as a change in long-term memory associated with schema construction and automation; and instruction is defined as the teacher's environmental arrangements for facilitating changes in the learner's knowledge (Mayer, 2008). According to Sweller and Chandler (1994), schemas represent the elements of knowledge stored in long-term memory. Schemas can reduce the cognitive load on working memory due to structuring multiple elements of information into a single element (Schnotz & Kürschner, 2007). CLT is based on three key assumptions about how people learn: (a) the active processing assumption, (b) the dual channel assumption, and (c) the limited capacity assumption (Mayer & Moreno, 2003).

Active processing assumption. This assumption is grounded in a cognitive approach to learning that views the learner as actively engaged in the process of knowledge construction (Clark et al., 2006). The process of knowledge construction includes cognitive processes such as paying attention to relevant material, mentally organizing material into a coherent structure, and integrating material with prior knowledge (Mayer & Moreno, 2003). Wittrock’s (1989) generative-learning theory and Mayer’s (1999, 2002) select-organize-integrate theory of active learning are additional examples based on this active processing assumption.

Dual channel assumption. The active processing mentioned under the first assumption is further qualified via the dual channel assumption. That is, the cognitive processing of information occurs in two separate channels: an auditory/verbal channel for processing auditory input and verbal representations, and a visual/pictorial channel for processing visual input and pictorial representations (Mayer, 2008). Several other researchers have proposed dual-channel processing along an auditory and visual channel including Paivio’s (1986) dual-coding theory and Baddeley’s (1998) theory of working memory.

Limited capacity assumption. This assumption adds another qualification to the active processing via two channels, namely the limited processing capacity of each channel in working memory (Clark et al., 2006). Miller (1956) proposed a general processing limit of “7 ± 2” chunks of information in working memory. CLT researchers have adopted the notion that working memory is limited (in capacity and duration) when processing new information and that these limitations disappear when dealing with information from long-term memory (Schnotz & Kürschner, 2007). Over the years, cognitive scientists have suggested different capacity limits, but general consensus exists that our mental storage capacity in working memory is indeed limited (see Cowan, 2000).

Types of Cognitive Load

In addition to the three processing assumptions, CLT researchers have posited different types of cognitive load when referring to the demands on working memory storage and information processing (Schnotz & Kürschner, 2007). Within CLT, the working memory resources required to learn a particular material are categorized into three types of cognitive load: intrinsic, extraneous, and germane load.

Intrinsic load. Intrinsic load refers to the amount of cognitive processing required to comprehend material and depends on the number of information elements and their interactivity (Clark et al., 2006). For example, reading comprehension for beginning readers constitutes a high intrinsic load task. To comprehend a sentence, the learner has to analyze each word and its relation to other words in the sentence. The element interactivity is high, because all elements have to be held simultaneously in working memory. Intrinsic load is determined by element interactivity; however, expertise determines what counts as an element (Schnotz & Kürschner, 2007). Schemas stored in long-term memory allow experts to process multiple elements as one element, thereby effectively decreasing working memory load. Consequently, instructional guidelines based on CLT are adjusted according to (a) the expertise of the learner, (b) the complexity of the content, and (c) the instructional methods used in the training environment (Clark et al., 2006).

Extraneous load. In contrast to intrinsic load, which is caused by task-intrinsic aspects of learning, extraneous load is caused by the (ineffective) format of instruction (Schnotz & Kürschner, 2007). All information processing irrelevant to the goals of instruction represents extraneous load (Mayer, 2008). CLT researchers have described extraneous load in two ways: (a) unnecessarily high degrees of element interactivity due to instructional format; and (b) instructional activities unrelated to schema acquisition and schema automation (Schnotz & Kürschner, 2007). According to CLT, all irrelevant cognitive activities should be eliminated, because they interfere with learning (Sweller, van Merriënboer, & Paas, 1998).

Germane load. Germane cognitive load is dedicated to the formation and automation of schema (Sweller et al., 1998). This type of load occurs when learners engage in “deep cognitive processing of the to-be-learner material, as reflected in the cognitive process of organizing and integrating” (Mayer, 2008, p. 24). Clark et al. (2006) noted that content variation in worked and practice examples (e.g., concept application in varied contexts) can yield germane load important for the generalization of schema. Mayer (2005) suggested that germane cognitive processing can be fostered by asking learners to engage in activities such as self-explanation of the material.

All three types of cognitive load are established in relation to the learner’s expertise. Cognitive load that is germane for a novice, for instance, may become extraneous for an expert

(Kalyuga, Ayres, Chandler, & Sweller, 2003). Moreover, CLT researchers assume that all three types of cognitive load are *additive* (Schnotz & Kürschner, 2007). Total cognitive load thus is the sum of intrinsic, extraneous, and germane load. This assumption explains why a reduction of extraneous load for simple tasks (i.e., low element interactivity) is not beneficial to learning outcomes: the combination of low intrinsic load and high extraneous load does not overload working memory. The assumption further explains why cognitive load effects were typically obtained for novice learners using materials of high element interactivity (Clark et al., 2006; Schnotz & Kürschner, 2007). To illustrate the interplay between the various assumptions and key terms, three major CLT effects are discussed next.

Cognitive Load Effects

A number of effects on persons' task performances have been observed using the CLT conceptual framework. A few of the most relevant to testing are the following:

Modality effect. Using materials that combine textual and pictorial information, CLT researchers such as Mousavi et al. (1995) and Mayer and Moreno (1998) demonstrated superior learning outcomes for students who were taught via narration and pictures (i.e., auditory and visual presentation) as opposed to learners who were taught the same material via written text and pictures (i.e., visual-only presentation). The modality effect can be explained based on the previously discussed dual channel assumption, which stated that visual and auditory materials are processed in two separate subsystems of working memory, each with a limited processing capacity (Brünken, Plass, & Leutner, 2004). In the visual-only presentation, the two sources of information had to be processed exclusively through the visual channel (and the processing capacity of the auditory channel remained unused). In the auditory and visual presentation, the textual information was narrated and thus processed through the auditory channel (while the pictures were processed through the visual channel). In other words, the auditory and visual presentation allowed students to utilize the processing capacity of both channels (Brünken et al., 2004).

The modality effect also applies to visuals (e.g., pictures, text) and auditory materials of high element interactivity (Clark et al., 2006). In each case, learning can be increased by utilizing both information-processing channels, which allows for the most efficient use of limited working memory resources (e.g., Carlson, Chandler, & Sweller, 2003). The modality effect, however, cannot be demonstrated for textual and pictorial information when (a) the two sources are comprehensible in isolation and (b) the two sources provide redundant information (Sweller, 2004). The issue of redundancy is further clarified via the redundancy effect.

Redundancy effect. The redundancy effect is demonstrated when eliminating duplicate content presentation results in improved learning outcomes (Sweller, 2004). The results of several studies demonstrated that removing redundant modalities (e.g., word-for-word narration of text, adding text or audio explanations to self-explanatory visuals) improved test score performance (e.g., Chandler and Sweller, 1991; Moreno & Mayer, 2000). The redundancy effect contradicts conventional wisdom about presenting the same content in different ways (e.g., reading power point slides). That is, redundancy requires the unnecessary processing of multiple sources of information that are self-contained (i.e., can be understood separately); and thus "wastes" limited processing resources (Clark et al., 2006; van Merriënboer & Ayres, 2005).

Split-attention effect. Split-attention occurs when multiple sources of visual information, which are spatially separated, must be integrated for comprehension (Schnotz & Kürschner, 2007). In other words, the individual sources of information cannot be understood in isolation and thus must be integrated in working memory. Tindall-Ford, Chandler, and Sweller (1997) demonstrated the split-attention effect using three versions of a lesson on testing electrical appliances. The first lesson version included text below a diagram (i.e., split unimodal format); the second version incorporated text beside the relevant parts of the diagram (i.e., integrated unimodal format); and the third version provided audio explanations in conjunction with the diagram (i.e., bimodal format). Posttest results of the groups instructed via the integrated unimodal and bimodal format were significantly higher than those of the group instructed via the split unimodal format.

The split-attention, redundancy, and modality effect were designed to demonstrate higher learning outcomes due to a reduction of extraneous load. Additional effects based on a reduction of extraneous cognitive load are the "goal-free effect", the "worked example effect," and the "completion problem effect" (van Merriënboer, Ayres, 2005). While a thorough discussion of these effects is beyond the scope of this paper, it is important to add that cognitive load researchers have begun to consider the intrinsic load within these effects as a property of the task-subject interaction (Paas et al., 2003). Recall that the discussed effects were demonstrated in studies of novice learners (i.e., students who lack relevant schemas) using challenging tasks (i.e., content of high element interactivity). Some CLT researchers (see Paas et al., 2003) interested in the task-subject interaction have begun to examine the extent to which the efficacy of the demonstrated effects changes as a function of learner knowledge (i.e., novice vs. expert). Kalyuga et al. (2003), for example, provided evidence that the beneficial effects of CLT-based instruction for novices (e.g., worked example effect) can have the opposite effects on learning outcomes when used with experts—the so-called "expertise reversal effect." The latter issue raises questions about the present limits of CLT.

Applications of CLT to Testing Students with Disabilities

Our current research enterprise is broadly focused on the inclusion of students with disabilities in standards-based instruction and assessment. Several "problems of practice" arise from the inclusion of students with disabilities in large-scale accountability systems. One problem is related to instruction: *To what extent are students with disabilities afforded the opportunity to learn the instructional content for which they are held accountable?* Another problem is related to measurement: *To what extent are the resulting test score interpretations valid?* Both questions are related to each other. That is, a necessary condition for the validity of test score interpretations is the students' opportunity to learn the assessed content.

To investigate these problems, we considered tools developed by educational psychologists for measuring the content alignment between different elements of the educational environment: curriculum, instruction, and assessment (Porter, 2002; Webb, 1999). These alignment models provided a quantitative index of alignment, which allowed us to consider additional relationships such as the relation between alignment and student achievement. Educational psychologists, of course, have a longstanding history of investigating the contributors to student achievement including motivation, self-efficacy, engagement, identity, and social skills (e.g., Anderman & Wolters, 2006; DiPerna, Volpe, & Elliott, 2001). In short, we interpreted alignment as a possible measure of opportunity-to-learn (OTL) and began to consider how alignment may be related to achievement. Initial results indicated a moderate correlation between alignment and student achievement confirming prior research (Gamoran, Porter, Smithson, & White, 1997). When grouped by general and special education, the results indicated that this moderate correlation maintained only for special education. As with most research, the findings prompted many more questions than answers: Can the findings be replicated? What are possible explanations for the differential results between general and special education? What interventions can increase teacher alignment? What extensions of OTL can be developed based on the alignment framework?

One application of CLT could pertain to an extension of the alignment framework. In the previous application of the Surveys of the Enacted Curriculum (SEC) alignment model, we accounted for the breadth (i.e., range of topics and instructional objectives) and depth (i.e., categories of cognitive demand) of the enacted curriculum (i.e., instructional content). Alignment indices between the enacted and intended curriculum were established in the same fashion for general and special educators. The relation between student achievement and teacher alignment conceptualized via the concept of OTL, however, did not incorporate an instructional dimension of the enacted curriculum. The SEC provided fine grain information on the content of the enacted curriculum, but no information on *how* that content was delivered. The "how" of content delivery, of course, is critical to special education. That is, special educators are supposed to be experts at adjusting the content delivery to the individual needs of their students (Quenemoen, Lehr, Thurlow, & Massanari, 2001). A conventional Individualized Education Plans (IEP) typically features a breakdown of applicable instructional modifications (e.g., preferential seating), but they tend to be general and suggest few instructional guidelines. The evidenced-based instructional guidelines of CLT could provide a third dimension of the enacted curriculum as measured by the SEC.

Another possible application of CLT related to the inclusion of students with disabilities in assessment is the concept of *accessibility* in testing. Beddow, Kettler, and Elliott (2008) defined accessibility as "the extent to which an environment, product, or service eliminates barriers and permits equal access to all components and services for all individuals" (p. 1). Applied to assessment, increased test accessibility provides students greater access to the test construct by reducing construct irrelevant variance. Greater accessibility thus permits more valid test score inferences. CLT primarily has been used to generate findings from which to provide direct instructional implications, specifically with regard to the adequacy of particular instructional designs. Chandler and Sweller (1991) described a series of studies conducted in Australia on electrical engineering trade apprentices. The results of these experiments indicated that cognitive load appeared to be lower when essential information disaggregated across two or more sources was integrated (e.g., textual statements describing a diagram were embedded in the diagram itself). Based on lower test scores and longer processing time for learners who were given the “split-source” diagrams, the authors concluded that “presentation techniques frequently result in high levels of extraneous cognitive load that influence the degree to which learning can be facilitated….For this reason…examples that require learners to mentally integrate multiple sources of information are ineffective”(Chandler & Sweller, p.295). As such, the predominant implications for instructional and testing practices pertained to the integration of graphics and visual representations with corresponding textual concomitants to reduce extraneous load.

Much of the recent CLT work has advanced these early applications of the theory to inform the development of multimedia instruction. Mayer and Moreno (2003) argued the potential is high in multimedia learning for “cognitive overload”(p.43) and provided five scenarios in which cognitive overload may occur, as well as research-based guidelines for preventing them. The authors employ three novel concepts to describe these scenarios: *essential processing, incidental processing, and representational holding*. Essential processing basically corresponds to intrinsic load and refers to the cognitive demand required to make sense of presented material (i.e., selecting, organizing, and integrating words and images). Incidental processing corresponds to extraneous load and refers to the demand from nonessential aspects of the instructional material. Representational holding refers to the demand required to retain verbal or visual information in working memory. We have found the work of Mayer and Moreno to have much to offer test designers.

The first type of overload scenario occurs when the essential processing in the visual channel is greater than the cognitive capacity of the visual channel. When the visual channel is overloaded by essential processing demands, Mayer and Moreno (2003) recommend off-loading some content to the auditory channel, producing a *modality effect*, whereby information is retained more easily when some portion is presented as audio narration than when the entirety is presented within single modality. Based on six studies, the median effect size of this strategy across six studies was 1.17. When both channels are overloaded by essential processing demands (scenario two), the authors recommend the use of two evidence-based strategies. The first is to segment the load, allowing time between portions of essential information (*ES* = 1.36; 1 study).

The second strategy is to provide pretraining with the aim of facilitating transfer of names and characteristics of essential components into long-term memory prior to the introduction of novel material (*ES* = 1.00; 3 studies).

The third scenario occurs when incidental processing due to extraneous material causes cognitive overload. The two recommended responsive strategies for this scenario are weeding (eliminating extraneous material; *ES* = 0.90; 5 studies) and signaling (providing cues to assist processing; *ES* = 0.74; 1 study). The fourth scenario occurs when incidental processing due to confusing material causes cognitive overload. When text is located apart from corresponding visuals, Mayer and Moreno (2003) suggested the visual scanning required to integrate the information causes confusion, thereby increasing the cognitive demand of the task. To reduce cognitive overload, they recommended aligning text and visuals to promote transfer between printed words and corresponding parts of graphics (*ES* = 0.48; 1 study). By contrast, they indicated information redundancy (e.g., of text and spoken words, text and visuals) also may cause confusion and cognitive overload. They recommended eliminating redundant information from one or more sources (*ES* = 0.69; 3 studies). Another strategy, suggested by Clark, Nguyen, and Sweller (2006) is to stagger the material, in essence developing a series of information cues whereby the presentation of novel material is reiterated by the redundant material.

The fifth and final scenario occurs when representational holding causes cognitive overload. The cognitive load of a task that requires representational holding of information in working memory prior to integration with other information may exceed the cognitive capacity of the learner. This typically is the result of temporal discontiguity: for instance, when a visual is presented and then removed, followed by a text description of the concept represented by the visual, the learner is required to hold a representation of the visual in working memory for a period of time before integrating the information with the later description of the visual. Similarly, if a task requires a learner to integrate information in one location (e.g., a page or a window) with information in another location, the requisite representational holding reflects an increase in the cognitive demand of the task. Mayer and Moreno (2003) recommend minimizing the need for representational holding by synchronizing information (e.g., presenting narration with corresponding animation simultaneously; *ES* = 1.30; 8 studies). They also conducting individualized assessment and training prior to instruction to ensure learners possess the ability to hold information in working memory to the degree required by the task (*ES* = 1.13; 2 studies).

Notwithstanding the broad overlap between instruction and testing, CLT heretofore has had little research application to school-age students with or without special needs or to the assessment of student learning. Considering the numerous similarities between instructional tasks and the variety of tasks required in many forms of tests, the development of the *Testing Accessibility and Modification Inventory* or TAMI (Beddow et al., 2008) focuses explicitly on the degree to which cognitive load demands may impact a test-taker's ability to demonstrate performance on assessments. Particular attention was paid to how CLT has been used to understand the cognitive demands of multimedia learning.

To the extent the cognitive demands of an assessment are intrinsic to the target constructs of the assessment, inferences made from test results are likely to represent the person's actual competence on the constructs. Extraneous load demands by an assessment item interferes with the test-taker's capacity to respond (i.e., demonstrate performance on the target construct) and should be eliminated from the assessment process. Further, germane load, while enhancing learning at the instructional level, should be considered for elimination as well: unless an assessment task has the dual purpose of both instruction and assessment, the items on a test should demand only those cognitive resources intrinsic to the target constructs they are intended to measure. Indeed, the addition of germane load to an assessment task may represent an increase in the depth of knowledge of an item if it requires additional elements or interactivity among elements. Thus, the decision to include or exclude germane load from assessment tasks should be made deliberately.

Beddow and colleagues (2008) have worked on the application of key CLT guidelines such as (a) using cues to focus attention on content, (b) reducing content to essentials, and (c) eliminating extraneous visuals, text, and audio (Clark et al., 2006) to modify test items. Research about the effects of modified items on student achievement is underway. Future work in this area includes examining the effects of modifications on student achievement for different groups of students (e.g., students with disabilities, students without disabilities), the interaction paradigm (see Kettler et al., 2008), and the differential effects of various types of modifications on student perception and student achievement.

A summary of CLT guidelines is provided as Table 1. It should be noted that not all of these guidelines are relevant to test design, but many are and we believe are worth using to design tests that are more accessible for all students.

Table 1. Cognitive Load Theory Guidelines: Applications to Item Modification and Testing

Guideline	**Concept / Clarification**	**Application to Testing**
1. Use diagrams to optimize performance on tasks requiring spatial manipulations.	All elements in a visual can be viewed simultaneously.	
2. Use diagrams to promote learning of rules involving spatial relationships.		
3. Use diagrams to help learners build deeper understanding.		
4. Explain diagrams with words presented in audio narration.	Working memory has two subcomponents: a phonological loop (auditory) and a visual-spatial sketch pad (visual). This complementary relationship is “the modality effect”	
a. Use audio to explain high complexity content		Use audio to explain high complexity content
b. Back-up audio with text to accommodate learners with hearing impairments		Back-up audio with text to accommodate learners with hearing impairments
c. Use audio for low prior knowledge learners		Use audio for low prior knowledge learners
d. Use audio only when diagrams and/or text require explanations		Use audio only when diagrams and/or text require explanations
e. Use text when content must be referenced during training.		Audio should not be used alone for content that may need to be referenced during completion of the item.
5. Use cues and signals to focus attention to important visual and textual content.	Cues = red circles, arrows and lines; Signals = italics, underlining, bold vocal emphasis. Concept: “More complex texts make additional demands on working memory and adding signals helps to offload some of those demands.”	Use bold for vocabulary words. Use red circles, arrows, and highlighting for important elements of visuals.

6. Integrate explanatory text close to related visuals on pages and screens.	Avoid “split attention.” Text and related visuals should not be separated on a page, on different pages, or screens.	Integrate explanatory text close to related visuals on pages and screens.
7. Integrate words and visuals used to teach computer applications into one delivery medium.		
8. Pare content down to essentials.	Eliminate redundant but related technical content.	Text economy.
9. Eliminate extraneous visuals, text, and audio. a. Omit extraneous words and pictures added for interest. b. Omit extraneous auditory content	Concept: Emotional vs. Cognitive sources of motivation. *Emotional* = Adding humor or interest; *Cognitive* = instructional methods used to support basic learning. Take-away: Invest resources in cognitive motivational elements.	Text economy; All included visuals are necessary.
10. Eliminate redundancy in content delivery modes.	When a visual requires further explanation, use *integrated text* or audio (to avoid split attention).	
a. Don’t add words to self-explanatory visuals	Adding audio or text explanations to self-explanatory visuals depresses learning.	Don’t add words to self-explanatory visuals
b. Don’t describe visuals with words presented in both text and audio narration.		Don’t describe visuals with words presented in both text and audio narration.
c. Sequence on-screen text after audio to minimize redundancy.		Sequence on-screen text after audio to minimize redundancy.
d. Avoid audio narration of lengthy text passages when no visual is present.		Avoid audio narration of lengthy text passages when no visual is present.
11. Provide performance aids as external memory supplements.	Factual information and procedure guides are the most common types of content included on performance aids.	

	(e.g., working aids, reference guides, wall charts, “cheat sheets” in lesson materials) (e.g., airplane safety card) Include 2 levels of learning: remember & use.	
12. Design performance aids by applying cognitive load management techniques. a. For spatial content, use visuals as the predominant display. b. Use graphics alone when the task can be effectively communicated visually. c. Use arrows or other motion cues rather than text to depict motion.		
13. Teach system components before teaching the full process.		Train test-takers in the test-delivery system prior to the test date.
14. Teach supporting knowledge separate from teaching procedure steps.		
15. Consider the risks of cognitive overload before designing whole task learning environments.		
16. Give learners control over pacing and manage cognitive load when pacing must be instructionally controlled.		
17. Replace some practice problems with worked examples.	*Worked examples* are step-by-step demonstrations of how to perform a task or solve a problem. Worked examples are more efficient for novices.	
18. Use completion examples to promote learner processing of examples.	*Completion examples* are hybrids between practice problems and worked examples. Essentially, the first step or steps is/are done for the learner.	

19. Transition from worked examples to problem assignments with backwards fading.	
20. Display worked examples and completion examples in ways that minimize cognitive load.	
a. Format worked examples in ways that manage cognitive load in multimedia through audio narration of steps and cueing of related visuals and in print media through integration of text nearby the visual.	Full worked examples are described with audio narration and cued with red circles to help learners see relevant portions as they are described.
b. Format completion examples with text that is integrated into the visual to avoid split attention.	
21. Use diverse worked examples to foster transfer of learning.	
22. Help learners exploit examples through self-explanations.	
23. Help learners automate new knowledge and skills.	
24. Promote mental rehearsal of complex content after mental models are formed.	
25. Write highly coherent texts for low knowledge readers. a. Organize sentence or diagrams that preview or review content. b. Include definitions and examples of unfamiliar terms. c. Use explicit statements that require minimal inferences. d. Use headers to signal paragraph topics.	

26. Avoid interrupting reading of low skilled readers.
27. Eliminate redundant content for more experienced learners.
28. Transition from worked examples to problem assignments as learners gain expertise.
29. Use directive rather than guided discovery learning designs for novice learners.

Conclusion

For over two decades, educational researchers have utilized CLT as a theoretical and empirical framework to generate testable hypotheses, conduct experimental studies, and design instructional guidelines. Over 100 peer-reviewed journal articles attest to the utility of CLT as a theory of learning and instruction (Clark et al., 2006). CLT researchers have generated evidenced-based instructional guidelines (Clark et al., 2006; Mayer & Moreno, 2003), which can provide practitioners important principles for designing their instructional materials to maximize efficient learning. The focus of CLT on efficient learning along the dimensions of task performance and mental effort can be applied to the design of highly accessible test items. In our recent efforts to design alternate assessments of modified achievement standards, CLT has played a significant role in guiding our refinement of items for standards-based achievement tests.

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