ICED 2020 proceedings: Maximizing learning using cognitive load theory

Robert Bledsoe[1]

English & World Languages, Augusta University
1120 15th St.
Augusta, GA 30912, USA

Deborah Richardson[2]

Department of Psychological Sciences, Augusta University
1120 15th St.
Augusta, GA 30912, USA

Abstract

This article describes how limitations of the human information processing system impact learning, and proposes that cognitive load theory (CLT) deserves more attention in educational development as a tool to respond to challenges posed by these limitations. Furthermore, we suggest that CLT can be used categorize and explain the effectiveness of many evidence-based teaching practices currently in use.

1 Introduction

As we move into the future, we are likely to continue to adopt teaching methods that are evidence-based and grounded in the science of learning and mental processing. Some of the most popular (English-language) books on teaching, such as those by Ambrose et al. (2010) and Lang (2016), show this movement to harness psychological research on the functioning of the brain. One productive avenue to explore in this context is work focused on the human information processing system and, more specifically, Sweller's cognitive load theory (CLT). This article explains how limitations of the human information processing system impact learning and considers instructional strategies and design principles to overcome those challenges in light of CLT.

2 The human memory system

Atkinson and Shiffrin (1968) identified three memory systems involved in human information processing. The (1) sensory system first selects information to move to (2) working memory, where the information is categorized and processed to move on to (3) long-term memory. A primary goal of instruction is to move information into long-term memory. However, the amount of information that working memory can hold at one time can interfere with that process. Miller (1956) demonstrated that working memory is limited to 7 ± 2 items. CLT argues that, since working memory has such a limited capacity, instruction should aim to avoid overwhelming the memory with activities and information that don't directly contribute to learning and the movement of information into long-term memory. While CLT has significant currency among educational developers, it has not been incorporated thoroughly into course design, instructional delivery, and learning. Since cognitive load can impact learning outside the

[1] rbledsoe@augusta.edu
[2] derichardson@augusta.edu

classroom, accurate information retrieval, critical thinking and the appropriate application of knowledge, CLT has important implications for teaching and instructional design in multiple contexts.

3 Cognitive load theory

Sweller distinguishes among three types of cognitive load. Extraneous load is load generated by external factors that interfere with cognitive processing, negatively impacting the learner's capacity to process material; for example, charts or tables that are difficult to read or contain unnecessary information can hinder learning. Even an ill-chosen font can increase extraneous load. Intrinsic load is load directly related to the material or task, and is often defined by the number of individual elements and interactivity between them; for example, arranging seating at an event acquires more intrinsic load as more demographic factors, such as age, family relationships, etc., have to be taken into account. Germane load is load on working memory capacity generated by accessing mental schemas and making connections necessary to move the material to long-term memory, therefore the germane load of a task will vary according to the subject's expertise. An expert will need to exert relatively little effort to take in new information and relate it to existing schemas, while a novice will need to expend extensive effort to generate a viable schema. Germane load is critical because it is effectively the cognitive activity that leads to information retention. Among researchers there is discussion of the value and appropriateness of distinguishing between intrinsic and germane load; however, we have found the distinction helpful in our project and will use it.

CLT researchers have identified a number of common problems, as well as techniques that facilitate learning. Redundant information, poor presentation formats that split attention (for instance between spoken audio and written text), inappropriate sequencing of learning tasks, and insufficient instructional support for learners can all increase extraneous cognitive load. On the other hand, providing worked examples can reduce intrinsic load. Similarly, assigning problems with varied features can help learners recognize deep features for better schema building, thereby facilitating effective use of germane load. Novices require more guidance than more advanced learners, so reducing guidance as students develop expertise facilitates learning. Scaffolding assignments has a role in this transition.

4 Implications

While educational development materials that refer to CLT often focus on cognitive overload produced by extraneous load, an examination of the effects of all three types of load can help us develop methodologies that maximize learning and create a tri-focal lens through which to think through course design, instruction and the evaluation of materials. To facilitate matters, let's distinguish between three key components of the instructional process: course design, activities in the instructional environment and activities that contribute to learning outside the instructional environment. Now, consider how evidence-based teaching and learning practices already in our tool set as instructors and as educational developers can contribute to the reduction of extraneous load and the maximization of intrinsic and germane load. We might come up with a chart similar to Table 1.

	Course design	**Inside the instructional environment**	**Outside the instructional environment**
Extraneous load	Select forms and frequency of assessment that reduce stress and promote deep learning. Select course materials that are easy to navigate and process.	Limit presentations to essential information. Minimize distractions.	Provide reading guides to help students identify essential concepts and material.
Intrinsic load	Scaffold activities to minimize the number of elements required to be held in short-term memory.	Gauge and activate prior knowledge. Reinforce component skills.	Focus assignments on one or a limited set of skills. Completion problems can reduce the number of interactive components.
Germane load	Recycle ideas and material to improve ability to recall from long-term memory.	Help students organize knowledge using organizing principles that fit the function. Facilitate transfer by making connections and material meaningful. Give students time to reflect.	Assign fewer problems, but require explanations of some solutions. Foster the development and improvement schemas. Have students make meaningful connections to other materials and individual goals.

Table 1: Selected evidence-based practices organized by cognitive load

One may argue about the placement of any one practice in a specific category. Indeed, some practices, such as providing reading guides and well-designed, “transparent” assignments, could impact all three types of cognitive load. However, it is more important to note how many of our current best practices can find a place in this table. In addition to generating a framework for organizing practices, CLT simultaneously offers an explanation for the value and effectiveness of these practices. This can be helpful when engaging with instructors who are not convinced to adopt a new teaching practice because it “worked for someone else,” but who want to know why and how it works.

5 Cognitive overload

Earlier we mentioned that much of the focus in educational development on CLT has revolved around the idea of avoiding cognitive overload and the reduction of extraneous load. It is important to recognize that cognitive overload can occur both within and outside of the instructional environment, and through all three types of cognitive load. Visual and audible distractions and attempts to absorb too much information without leaving adequate time to retrieve schemas and process information can impede learning not only in the classroom, but also when students are studying and working by themselves or with others. Therefore, just as instructors should be guided to check and verify comprehension using, for instance, classroom assessment techniques, so do we need to encourage students to foster metacognitive practices that will help them avoid, recognize and deal with situations of cognitive overload.

Klepsch, Schmitz, and Seufert (2017) have developed instruments to measure the different types of cognitive load in specific learning situations. Among items on the instruments are statements such as “For this task, many things needed to be kept in mind simultaneously” (instrinsic CL); “The learning task consisted of elements supporting my comprehension of the task” (germane CL); “During this task, it was exhausting to find the important information” (extraneous CL). Prompts such as these can be used not only to evaluate materials and activities, but to help students with appropriate training recognize learning difficulties and challenges and select strategies that allow them to avoid overload and to respond appropriately when it does occur.

6 Conclusion

In sum, cognitive load theory provides a framework for educational development aimed at improving teaching practices. Of course, some caution is called for. As implied by its name, CLT focuses on the distribution and use of cognitive resources. Kalyuga (2015) has noted that CLT does not consider affective factors that we recognize are important to learning, such as engagement and motivation. Therefore, integrating CLT with other theoretical frameworks that can account for the significance of socio-affective factors to learning will be important in developing a robust understanding of learning. Nevertheless, as an organizing mechanism and as a way to explain the effectiveness of evidence-based teaching practices it is a valuable tool that deserves further use by educational developers.

References

Ambrose, S., Bridges, M. W., DiPietro, M., Lovett, M. C., & Norman, M. K. (2010). *How learning works: Seven research-based principles for smart teaching*. John Wiley & Sons.

Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory: A proposed system and its control processes. In K. W. Spence & J. T. Spence (Eds.), *The psychology of learning and motivation* (vol. 2, pp. 89-195). New York: Academic Press. https://doi.org/10.1016/S0079-7421(08)60422-3

Kalyuga, S. (2015). *Instructional guidance: A cognitive load perspective*. Information Age Publishing, Inc.

Klepsch M., Schmitz, F., & Seufert, T. (2017) Development and validation of two instruments measuring intrinsic, extraneous, and germane cognitive load. *Frontiers in Psychology, 8*,1997. https://doi.org/10.3389/fpsyg.2017.01997

Lang, J. M. (2016). *Small teaching: Everyday lessons from the science of learning*. Jossey-Bass.

Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review, 63,* 81-97. https://doi.org/10.1037/h0043158

Sweller, J. (1988). Cognitive load during problem-solving: Effects on learning. *Cognitive Science, 12*, 257-285. https://doi.org/10.1207/s15516709cog1202_4