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Cognitive load theory: more food for thought

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Introduction

A scientific theory is an explanation of a set of related observations, phenomena, or events based upon one or more hypotheses and verified multiple times by the evidence of detached groups of researchers. Cognitive load theory (CLT) was designed "to provide guidelines intended to assist in the presentation of information in a manner that encourages learner activities that optimize intellectual performance (Sweller et al. 1998 p. 25)." The theory proved successful in inspiring many experimental studies aimed at testing the CL effects of instructional design for over 20 years (Clark et al. 2006). On the other hand, a growing number of educational psychologists and researchers has identified many conceptual, methodological, and practical limitations of the theory (Bannert 2002; Brünken et al. 2009; Horz and Schnotz 2009; Moreno 2006; Schnotz and Kürschner 2007). The concerns voiced by de Jong (this issue) resonate with those critiques and suggest the need to reflect carefully on the scientific value of the theory.

Does CLT meet the rigor of scientific theories? In this article, I comment and expand on Jong's criticisms from the perspective of a cognitive-affective theory of learning and discuss the implications of CLT's challenges for advancing the science of learning and nurturing a scientific culture in educational research.

Conceptual limitations of CLT

One of the major conceptual issues identified by de Jong in the literature concerns the lack of clarity about the CL construct itself, especially in relation to the constructs of intrinsic cognitive load (ICL), mental load, and mental effort. Early psychological theories have defined mental load as the psychological experience that results from the interaction of subjective individual characteristics and objective task characteristics (Campbell 1988;

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Wood 1986), with mental effort being one of the many sources of mental load (Kantowitz 1987). As a psychological experience, mental load cannot arise before the learner has engaged in a learning task. Because ICL is defined objectively, as the extent of interactivity of the material to-be-learned (Sweller and Chandler 1994), de Jong argues that its inclusion as one of the three components of the CL experienced by a learner is problematic.

A second obstacle faced by CLT since the triarchic theory of loads was proposed (Sweller et al. 1998), is demonstrating the distinctiveness of the extraneous cognitive load (ECL) and germane cognitive load (GCL) constructs and predicting CL and learning outcomes that are based on this distinction. de Jong provides compelling evidence in support of the following issues: (a) methods that *prima facie* seem to induce extraneous load may also induce germane load and vice versa; (b) because the type of load is highly dependent on learner characteristics and learning objectives, the ECL and GCL constructs are ambiguous; (c) because the definitions of ECL and GCL are tautological (ECL is 'bad', unnecessary load and GCL is 'good', necessary load for schema acquisition), only *ex-post facto* explanations of the findings can be offered; and (d) the research shows many contradictory results or findings that go against CLT's predictions (De Croock et al. 1998; Große and Renkl 2006; van Merriënboer et al. 2002).

The third major conceptual issue in CLT surrounds what has been called 'the additivity hypothesis' (Brünken et al. 2009), the idea that "intrinsic, extraneous, and germane cognitive loads are additive in that, together, the total load cannot exceed the working memory resources available if learning is to occur (Paas 2003, p. 2)." de Jong questions this assumption by arguing that ICL has a different ontological nature than the other two load types; in other words, we cannot add apples and oranges. Recent evidence, however, shows that the additivity hypothesis does not hold, even when ICL is controlled for (Koch et al. 2009; Park et al. 2009). Robust extraneous load effects found in the original CL research revert when the same methods are used in combination with methods aimed at increasing schema acquisition (Park et al. 2009) and no support is found for the hypothesis that learning with decreased extraneous load and increased germane load leads to lower levels of CL as compared to learning with decreased extraneous load and decreased germane load (Seufert and Brünken 2006).

Methodological limitations of CLT

The methodological issues in CLT are as central as the conceptual ones. de Jong and others have discussed the strengths and limitations of the objective and subjective measures of CL used in the past (see also Brünken and Seufert 2009; Brünken et al. 2003; Brünken et al. 2009). The conclusion is clear: There are no standard, reliable, and valid measures for the main constructs of the theory.

In contrast to the large number of studies that have used CLT to frame the research questions and predictions as a framework, insufficient attention has been given to the rigorous development of CL measures. Many recent studies continue to use some version of the first self-reported measure of total CL, a one-item scale of perceived mental effort (Paas 1992). This is disappointing considering that the evidence for the reliability and validity of this scale seems to rely exclusively on one study by the same authors (Paas et al. 1994). Construct validity should be supported by amassing convergent, divergent, and content-related evidence to determine that the presumed construct is what is being measured. In addition, according to classic measurement theory, one-item scales are inappropriate construct measures. Internal consistency indices can only be estimated with measures that have more than one item (Ong and van Dulmen 2007). Moreover, the one-item scale asks individuals to rate their perceived amount of mental effort invested, which is only one of the components of CL.

Several other methods have been proposed as an alternative to the one-item rating. Objective measures do not distinguish between the three load types and are rare due to their intrusiveness; efficiency measures are not adequate to test the assumptions of CLT and seem to be favored when CL measures do not show expected treatment effects; and a variety of other self-reported instruments are used without presenting evidence for their psychometric properties. Finally, as cited by de Jong, cognitive capacity is only rarely measured in the research (van Gerven et al. 2002, 2004). This is noteworthy for two reasons. First, unlike the CL construct, excellent measures of cognitive capacity can be found in several intelligence test batteries. Second, CLT predicts that overload (and lack of learning) occurs when the total amount of load induced by the learning environment exceeds the maximum cognitive capacity of the learner. Without a measure of cognitive capacity, the predictions of CLT cannot be tested.

A cognitive-affective theory of learning perspective

A cognitive-affective theory of learning is based on learning science principles (Moreno 2005; Moreno and Mayer 2007) and offers an integrative model where cognitive processing is the result of the interaction among the learner's knowledge, abilities, beliefs, affect, and motivation. Affect acts as the on/off switch to motivation, which is the process by which goal-directed behavior is initiated and sustained either consciously or unconsciously (Moreno 2009a). Implicit in this integrative model is the idea that cognitive capacity is a parameter that students bring to the learning task whereas motivation determines the actual amount of cognitive resources invested in the learning task.

It is important to note that this theory does not explain learning in terms of CL. Similar to the cognitive theory of multimedia learning on which it draws (Mayer 2005), the cognitive component of the theory distinguishes among extraneous, essential, and generative *processing*. In agreement with de Jong, I will argue that because CLT has not attempted to clearly specify the characteristics of mental processes that promote 'good' versus 'bad' load, the research has been unable to unequivocally predict the outcomes of different instructional methods on ECL, GCL, total load, and learning. Next, I present some additional CLT issues under the light of a cognitive-affective theory.

First, CLT should consider extending its conceptualization of prior knowledge beyond knowledge about the subject domain. Many studies have shown that prior experience with other task-specific components, such as students' familiarity with specific knowledge representations, instructional methods, or media are not less diagnostic of learning and should be given appropriate consideration in any theory of CL (Moreno 2009b; Moreno and Durán 2004; Moreno and Mayer 2002).

Second, a cognitive-affective theory argues that it is the actual amount of cognitive resources spent rather than the maximum cognitive capacity that affects learning. CLT is remarkably silent about the relation among load, affect, and motivation. This void is extremely problematic under the light of decades of empirical evidence showing the tight interconnectedness among these constructs (Dai and Sternberg 2004; Keller 1987; Meinhardt and Pekrun 2003; Pintrich and Schunk 2002; Wigfield et al. 2006). For instance, difficulty level will mediate students' motivation to learn which, in turn, will affect the amount of invested effort during learning. A task that is too easy or too difficult is likely to undermine students' motivation. In both situations, because the learner is working outside of his/her zone of proximal development (ZPD; Vygotsky 1986), it is likely that he/she will not invest sufficient cognitive resources in the learning task. CLT fails to adequately explain this phenomenon by treating difficulty as a factor that is objective. Consequently, CLT is unable to unequivocally predict the learning outcomes resulting from working under, within, or beyond the ZPD and to explain why the same learner may fail to learn under two qualitatively different load conditions: tasks that are too easy or too difficult.

A cognitive-affective theory of learning also predicts that the amount of invested effort will depend on students' *beliefs* about themselves and the learning task. Even if the task is designed well-within learners' ZPD, if the learner does not believe that he/she can be successful, cognitive resources will not be invested in the task at hand and learning will not occur (Weiner 2000). Likewise, learners who have high success expectations choose more challenging tasks, persist more under difficulty, and perform better than those with low success expectations (Eccles et al. 1998). The perceived value and cost of engaging in the learning task (Thrash and Elliott 2001) and the personal or situational interest of the learner (Hidi and Renninger 2006) will affect the amount of cognitive resources that students invest as well.

Another omission from CLT is self-regulation. Learners who are self-regulated are able to expand on their effective cognitive capacity by using more learning strategies, better monitoring their learning, and more systematically evaluating their progress towards learning goals than their counterparts (Boekaerts 2006). Despite the fact that these behaviors affect the management of limited cognitive resources during learning, CLT does not currently give insights about the effects of self-regulation on the load types and learning (Bannert 2000, 2002). In sum, despite the strong effect that affect and motivation have on psychological and behavioral phenomena during learning, CLT remains "cold".

Conclusion

A major goal of science is the construction of good theories, which are those accepted by the scientific community because they are able to explain or make predictions of events. To meet the standards of a scientific theory, CLT's assumptions about the relation between the human cognitive architecture, instructional design, and learning should do the following. First, the theory should provide a good conceptual framework for explaining the examples of learning and instruction that we observe. Consider what is taking place at any point in a lesson, from the student's perspective. Note that the student brings to the learning situation a set of abilities, a certain emotional state, and a certain level of motivation, experiences, and knowledge. The latter includes knowledge of the content, of the task, of the various scripts and schemata for dealing with the content and task, and a complex set of self-beliefs and beliefs about learning, the content, and the task. The question, given our understanding of CLT is: How will those factors affect the learner's CL and learning and (more importantly) why? In prior sections, I have attempted to describe the major constraints behind CLT's response to this question.

Second, CLT should be able to predict psychological or behavioral phenomena resulting from instructional design. The question here is: Can CLT accurately predict the effects that instruction has on the main constructs of interest, namely, ICL, GCL, ECL, and learning? de Jong's exhaustive review of the literature shows that serious conceptual and methodological limitations need to be surmounted before the research can adequately test the theory's predictions. Hypotheses that cannot be put to the test of evidence may be interesting, but are not likely to be scientifically useful.

The fact that theories are never proven and subject to continuous scrutiny and improvement is the great strength of science and the reason why scientists do research. Even though many empirical studies have helped refine CLT in the past (for a review see Moreno and Park 2009), no significant advances are evident since the triarchic theory was proposed (Sweller et al. 1998), suggesting that the theory is at an impasse (Moreno 2006). The most recent evolutionary interpretation of CLT is interesting (Sweller 2003, 2004) but does not address the fundamental concerns surrounding the theory. As a result, the dissatisfaction about the explanatory and predictive value of CLT continues to grow among the scientific community.

Under the light of CLT's fundamental limitations, I will make the argument that continuing to use the theory to frame instructional design research is instilling the idea that educational research cannot aspire to have the same scientific value as that of the hard sciences (Diamond 1987). The following are some reasons why this might be the case. When educational researchers are not able to demonstrate that they are making progress, they give further reasons to believe that the learning sciences are a lesser form of knowledge (Labaree 1998). Second, although a strength of CL research is the use of controlled experimental studies—one of the exemplary methods of scientifically based research (Eisenhart and Towne 2003)—it has failed to develop adequate methods that permit direct investigation of the research questions at stake. Science relies on measurements or observational methods that provide reliable and valid data across studies by the same or different investigators (National Research Council 2002).

Third, in any science, researchers construct towers of knowledge on the foundations of the work of others. de Jong raises a valid concern about the fact that CL research often ignores the existence of earlier research and theories that may better account for the findings than CLT. The dangers of this isolated approach to science are clearly stated by Labaree (1998) "At the end of long and distinguished careers, senior educational researchers are likely to find that they are still working on the same questions that confronted them at the beginning. And the new generation of researchers they have trained will be taking up these questions as well (p. 9)."

Lastly, although bias may not be completely avoidable, scientists are expected to be aware of potential bias sources in their work. One safeguard against bias in any area of study is to be open to reflection and scrutiny. It is the professional responsibility of educational researchers to evaluate the state of current knowledge on a regular basis, identify knowledge gaps, and lay the scientific principles for future investigation. Engaging in this 'effortful' practice is key in fostering a scientific community and culture.

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