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Contemporary cognitive load theory research: The good, the bad and the ugly

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ABSTRACT

This paper reviews the 16 contributions of the special issue entitled *Current Research in Cognitive Load Theory*. Each paper is briefly summarized and some critical comments made. The overall collection is then discussed in terms of the positive contributions they make to the field of learning and instruction, and cognitive load theory in particular (the *good*), as well as problematical issues such as unresolved explanations and conflicting results (the *bad*) and the special case of measuring cognitive load (the *ugly*).

1. Introduction

Since its development in the 1980s, cognitive load theory (CLT) has identified many effects such as worked examples, temporal and spatial split-attention, redundancy, modality and expertise reversal (for summaries see Sweller, 1999; Van Merriënboer & Ayres, 2005; Van Merriënboer & Sweller, 2005) that influence instructional design. The papers in this special issue show the broadening of the research base and indicate the variety of research groups studying CLT. This article discusses 16 studies which are based on the 3rd Internal Conference on Cognitive Load Theory in Heerlen, the Netherlands. They represent a cross-section of contemporary research into CLT. We have utilized the well-known colloquialism the *good*, *the bad and the ugly*, in the title, as it provides a useful framework to sums up our observations on the papers. There are very positive aspects to the studies particularly the focus on well conceptualized random controlled studies which measure learning outcomes. It is an unfortunate reality that the field of cognition and learning continues to lack from evidenced based theory driven research and the current studies provides an ongoing valuable contribution to the field. There also some issues that we consider more problematic and require attention to ensure the future quality of cognitive load research. We have grouped the papers together into three sections, which we have called: (a) learning in complex environments, (b) learner control and choice; and (c) animated and multimedia instruction. We start our discussion by reviewing each individual paper, and conclude by identifying the different issues that could be considered the good, the bad and the ugly of the current papers.

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2. Individual paper summaries and discussions

2.1. Learning in complex environments

As society and work environments become more interconnected and complex, it is increasingly relevant that cognition and learning research is carried out in environments that 'mirror' the complexity of the real world. One of the major strengths of cognitive load research over the years is that it has increasingly focused on complex learning environments and real life school and industry settings (Chandler & Sweller, 1991, 1992, 1996; Ward & Sweller, 1990). The first set of contributions to this special issue all deal in one way or another with learning and instruction in complex environments.

The contribution by Schwonke, Renkl, Salden, and Aleven (2011) investigated the effects of different ratios of worked solution steps (high assistance) and to-be-solved problem steps (low assistance) on cognitive skill acquisition in geometry using a cognitive tutor. Based on the *Assistance Dilemma* (see Koedinger & Aleven, 2007), they assumed an inverted U-shaped relation between the number of worked steps and learning outcomes with neither the highest proportion of guidance (i.e., many worked steps with little problem solving practice) nor the lowest proportion would be optimal for learning. The authors assume in their research that they can directly assess extraneous load by asking learners how difficult it was to study or solve the problems. We will return to this in the discussion further on in this article. In agreement with Kirschner, Sweller, and Clark (2006), the authors found that problem solving induced more extraneous cognitive load than example based learning-irrespective of the ratio of worked steps and to-be-solved steps. Together with a pattern of substantial negative correlations between extraneous load and learning outcomes, this corroborated the notion that the worked-example effect is based upon reduction of extraneous load.

Kalyuga and Hanham (2011) researched whether learning flexible problem-solving skills could be enhanced by explicitly instructing learners in generalized forms of schematic knowledge structures applicable to a greater variety of problems. They reasoned that such structures direct learner attention toward essential characteristics of novel problems and be associated with top-down types of transfer (Bassok & Holyoak, 1993). To this end they propose a general schematic framework for describing different man-made products in technical domains based upon the assumption that technical objects can be characterized by their functions/purpose, the processes utilized in their operation, and their internal structure; the *functions-processes-structures* (*FPS*) *framework*. Kalyuga and Hanham compared direct instruction in the FPS schematic framework with a conventional format without explicit schema-based instruction. The schema-based instruction used two alternative procedures, a gradual hierarchical multilevel introduction of the FPS schema and a single-level introduction. The differences between the three formats were not significant on a retention test but were significant for transfer, where the hierarchically structured condition performed marginally better (i.e., not significant) than both other groups. They speculate that the results indicated that there was a "possible effect of enhancing learner abilities in handling relatively new (transfer) problems" when explicit instruction via the FPS schema was used.

Berthold, Röder, Knörzer, Kessler, and Renkl (2011) studied whether and to what extent *explanation prompts* as an instructional support feature induce active processing while at the same time looking at whether, as Sweller (2006) states, they take cognitive load to the upper limit of working memory capacities when learning with complex learning materials. Their contribution to this issue continues Berthold, Eysink, and Renkl (2009) work on using explanation prompts to focus the processing of concepts to the field of procedural learning. To this end, they studied the positive and negative effects of conceptually-oriented explanation prompts in a complex e-learning module on learning outcomes (i.e., conceptual and procedural knowledge), learning processes (i.e., prompts responses and annotations), and cognitive load (i.e., intrinsic and extraneous load). They found that explanation prompts had a positive effect on both the quantity and quality of explanations during learning, but that the prompts also prevented learners from considering necessary arithmetical operations during learning, thereby, hindering acquisition of procedural knowledge. They call this the *double-edged* effect of using prompts.

While modern education strongly advocates working in groups and collaborative learning environments, very little research actually moves beyond fuzzy "feel good" explanations as to how and why group learning can be beneficial. The work of Kirschner, Paas, and Kirschner (2011) distinguishes itself from much of the field by examining the cognitive underpinnings of collaborative learning. Their contribution to this issue continues their earlier work (Kirschner et al., 2011) which examined the interaction between complexity and group learning. In a nutshell, Kirschner et al.'s (2011) research found that the efficiency of group learning is tempered by information complexity (referred to as element interactivity within cognitive load theory). Quite simply, when learning material is low in complexity, individual learning is superior. However, when learning complex information collaborative learning is more effective than individual learning. They confirm the "group" effect with mathematics based material. Both performance and cognitive load measures confirm their hypotheses. The result is significant in that it indicates that the "group" effect may have a degree of robustness and generality across disciplines. Interestingly, the authors propose that self-efficacy expectations (or more precisely collaborative collective efficacy) may be a meditating factor involved with the group effect. They suggest that when groups work together on complex instructions they have a heightened level of confidence in their ability, as they are aware they can spread working memory load amongst other members of the group. This interpretation of the results while interesting is at this stage speculative and requires further research including incorporating measures of collective efficacy (Hanham & McCormick, 2009). However, it is apparent from this paper and previous work that group learning is proving to be a promising vein of research for cognitive load theory. In addition, the research has the potential to build research bridges between purely cognitive and motivational understandings of group learning.

2.2. Learner control and choice

Giving learners control of their learning environments is quite a seductive prospective. The move from instructor based to student controlled learning environments certainly has much inherent appeal. Though the last decade has seen a strong global push in this direction at all levels of education, the empirical realities of this push are a little different. While some learners benefit from learner control others struggle greatly (Katz & Assor, 2007; Kopcha & Sullivan, 2007). As Corbalan, Kester, and Van Merriënboer (2011) so concisely note, "[T]oo much control causes cognitive overload and even experts might experience difficulties in selecting, sequencing and pacing huge amounts of information". The discussion of the following papers will examine studies that focus on the role of learner control and provided much needed evidenced based guidelines for their use in education.

Within a CLT framework, research has consistently shown that while high-knowledge learners and advanced learners may benefit from student control formats, less experienced learners flounder due to the heavy cognitive load requirements of unstructured learner-controlled environments. Extensive research within the expertise reversal paradigm effect (see Kalyuga, 2007; Kalyuga, Chandler, & Sweller, 1998; Kalyuga & Sweller, 2005) has established that the level of expertise is the key factor mediating the use of control in learning environments. The higher the expertise the more effective learner control is.

Using a cognitive load framework, Mihalca, Salden, Corbalan, Paas, and Miclea (2011) examined the role of learner control on performance and instructional efficiency using a genetics training program. In their study comparing three types of instruction (i.e., non-adaptive program control, adaptive program control, and learner control), they predicted that adaptive control would be more effective than both other groups as it better met the needs of learners than program control and was less load bearing than learner-controlled environments. While there is some evidence that adaptive control was effective in terms of instructional efficiency the results did not generalize to test-performance measures (near or far transfer). While the study showed considerable promise for embedding adaptive program control into technology based instruction, there is a clear need to tease out the testing issues and replicate this work.

Schwamborn, Thillmann, Opfermann, and Leutner (2011) investigated the potential benefits of utilizing learner generated and instructor provided illustrations with textual science based instructions. Utilizing CLT, they predicted that both learner and instructor generated computer illustrations would be advantageous for learning. Results indicated that instructor generated illustrations aided comprehension and understanding of science materials and led to less cognitive load and lower perceived task difficulty. Learner generated illustrations did not seem to be as effective. The findings were consistent with CLT and demonstrated that for inexperienced students, generating their own illustrations may impose excessive cognitive load and reduce learning. As the authors point out, this work needs to be extended with more experienced students where the results may turn out differently. Their