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Commentary 2

Cognitive load: updating the theory?☆

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Abstract

This special issue presents a very varied vintage of recent theoretical developments and empirical research that help to found to a further extent the Cognitive Load Theory (CLT) as it was conceptualised by Sweller and others in the late eighties (Cognitive Science 12 (1988) 257).

The present article does not present individual commentaries on each contribution of this special issue. Another strategy has been adopted because we aim at—considering the title of this contribution—extending Cognitive Load Theory and orienting further research. Three basic ‘new’ directions are suggested. The first one is related to the potential of CLT to ground—next to cognitivist approaches—also constructivist approaches to learning and instruction. The second new direction looks at a neglected process in CLT that is related to the monitoring activities that occur during the learning process. We postulate—building on current CLT theory, current research and other work in the field of learning and instruction—the need for an extra perspective on cognitive load: metacognitive load. Thirdly, we present an attempt to position the notion of prior knowledge in the context of CLT. © 2001 Published by Elsevier Science Ltd.

1. CLT: cognitivist and constructivist approaches to learning and instruction

A number of authors in this special issue refer in their article to constructivism (Kirschner in his introduction and Mayer & Moreno in their article). But the relationship between constructivism and CLT is hardly made clear.

Kirschner introduces the special issue with two key sentences that already offer a base for the extensive discussion we present in the second part of this article. The abstract starts with the sentence: “Cognitive load theory can provide guidelines to assist in the presentation of information in a manner that encourages learner activities

☆ Edited by Paul A. Kirschner. With Martin M.A. Valcke and Maria Bennett
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that optimise intellectual performance”. And the introduction starts with “In educational contexts there is a growing call for competency-based education”. At the one hand Kirschner clearly shows that specific focus of CLT where it helps to describe and explain specific cognitive process. On the other hand, there is the underlying ambition to offer directions to guide instructional processes. “Presentation of information” is of course an essential part of instructional processes. It therefore sounds very seductive to accept CLT-principles to inspire specific instructional strategies.

The question now arises how compatible this is with new instructional theoretical developments. Constructivism, e.g., forces us to reconsider the active role of the learner in the learning process. The question of offering ‘representations’ to learners is—given this alternative perspective—to be reconsidered. How does CLT account for learning processes in which learners actively construct external representations. The new generation of tools to construct mind maps, Of course, this critique does not touch the credibility of CLT to explain and describe cognitive processes. But, it touches the implications we can derive from CLT to direct instructional processes. CLT seems to be naturally linked to cognitivist views upon learning and instruction. The publication of Sweller, van Merriënboer, and Paas (1998) exemplifies this dominant focus on cognitivist instructional interventions (goal-free problems, worked examples, completion problems, ...). Also the research of Pollock, Chandler and Sweller, presented in his special issue, reinforces this view upon CLT since they focus on ‘presentation’ features of information by the instructor or designer of the learning environment.

In a way, CLT recognizes the need for a shift of focus by the attention currently paid to germane cognitive load. It is the former that is responsible for the construction of adequate and rich schema. The article of Van Merriënboer, De Croock, Schuurman and Paas is of high importance in this perspective. Their second and third study in which they focus on germane cognitive load (study 2) and redirect attention by simultaneously decreasing extraneous cognitive load and increasing germane cognitive load (study 3) show how training efficiency is optimised. They suggest this as a direction for future research and as a link to theories of self-directed learning. Here the learner is in control. As a consequence, cognitive scientists ask for learners to adopt techniques to make their own representations more explicit (cf. Gagné, Yekovich, & Yekovich, 1993, p. 128).

If CLT would continue to work in these two directions it could become able to make an extremely important contribution to the foundation of the constructivist perspective on learning and instruction, next to the further foundation of the cognitivist perspective.

The research of Mayer and Moreno, presented in this issue, gives us several ways to link CLT to a constructivist frame of reference. First of all, the authors stress the fact that constructivism is grounded on the assumption that the learner is the active constructor of his/her own schemas and as such builds on his/her own cognitive activity. Secondly, the authors state that in contexts where learners are in control of elements in the learning environment, learning results are higher. These findings are related to the learning context in which the learner is given the opportunity to choose

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between knowledge representations in the learning environment (modality research). Thirdly, the authors stress the fact that learning is better to be based on multiple representations of knowledge, again a typical constructivist assumption.

The contribution of Van Bruggen, Kirschner and Jochems in this issue is the most challenging to study the link between CLT and constructivist learning principles. The authors state that “the two meet in the use of external representations”. We think that the contribution of these authors goes beyond this first focus. The authors also stress that fact that they do not only point at mere ‘construction’ of such representations. They stress the fact that constructivist learning environments should foster this construction activity of (external) representations (as ‘embryo’s of internal representations, also called schemas). CLT offers guiding principles in this context where it suggests to use worked examples bin the initial stages, to promote sharing representations an meanwhile reducing cognitive load.

Firstly, this is due to the attention they pay to the ‘collaborative’ set-up of the learning process. Secondly they introduce a special activity: sharing external representations. This is exactly in line with the critique we presented earlier: move away from the mere presentation of a representation to the construction of external representations. Moreover, in line with social constructivist assumptions, the authors urge learner to ‘share’ representations. This forces learners to be more explicit about their schemata. Elaboration and organisation of schema is thus fostered. But the authors hypothesize that this co-construction of representations will generate high levels of cognitive load. They present solutions to reduce cognitive load (e.g., worked examples), but they also indicate limitations of this strategy. They rightly refer to ontological issues. This is to be related to the epistemological base of constructivism: knowledge is to be grounded in the active construction (of schema) by learners.

2. The case of meta-cognitive load

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Cognitive Load Theory builds upon the cognitive perspective on learning. CLT concepts, such as long term memory (LTM), short term memory (STM, working memory) and schema construction are key concepts that go back to the information processing approach to learning. It is remarkable that the further development of CLT had not made an attempt to incorporate some other features of the information processing model. We especially stress here the importance of the monitoring activities that influence the different processes: monitoring/controlling the selection and organisation of sensory information to working memory; back and forth storage and retrieval of schemas from LTM to STM; organisation monitoring of output; etc. We suggest in this paragraph to extend CLT with the conception of monitoring; more specific the explicit monitoring of cognitive processes, also called ‘meta-cognition’. As will be argued, we present a case for entering a specific kind of cognitive load, called ‘meta-cognitive load’.

Some authors in this special issue mention meta-cognition, but they do not elaborate the relationship between this concept and CLT and certainly do not integrate the concept in the overall CLT (see the article of Kirshner and the contribution of Stark,

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Mandl, Gruber & Renkl). The fact that meta-cognition is neglected can be related to the types of knowledge, the researcher focus upon during their researches. The focus is on declarative and procedural knowledge in a variety of knowledge domains (computer programming, statistical problem solving, system failures, process control, geometry procedures, etc.). Meta-cognitive knowledge has not been considered.

The distinction between intrinsic, germane and extraneous cognitive load is relevant at a theoretical level and can—in part—be empirically grounded. But as to germane cognitive load we can ask for a further distinction. Learners invest effort in the construction and storage of schemata. But they also invest in the monitoring of this activity. This implies that we have to consider whether part of the overall germane cognitive is to be linked to the latter activity. Why not calling this germane ‘meta-cognitive load’? The theoretical and instructional implications of this extra distinction are far-reaching. First of all, CLT is enriched by its ability to cope with the monitoring activities and thus integrating a meta-cognitive perspective in its frame of reference. Next, the instructional implications urge researchers to research the impact of instructional strategies that focus upon the incorporation of meta-cognitive awareness. We can e.g., instructional strategies that force learners to reflect explicitly upon their processing activity and/or strategies during which learners are offered met cognitive tools that help to make explicit the steps they take, their reflection upon these steps, their doubts and feelings of surity, etc.

A number of contributions to this issue offer a starting point to discuss meta-cognitive load in the context of CLT. In the discussion of their experiments, Van Merriënboer, De Croock, Schuurman and Paas indicate the fact that learners in the learner-controlled group do fully use freed-up processing capacity to start processes direct relevant to learning (increasing germane cognitive load). This suggests that the ‘learner-controlled’ experimental set-up allowed for monitoring the learning process invoking meta-cognitive load as part of germane cognitive load, and this with lower mental effort.

The study of Stark, Mandl, Gruber and Renkl (this issue) contributes in two ways to our argumentation. First of all, the article focuses explicitly on cognitive and metacognitive aspects of example elaboration in view of its impact on mental load of learners. They consider metacognitive load, but they do not include it in the training. They assume that metacognitive example elaboration, is intensified by the overall elaboration training. They try to invoke deep processing with specific instructional strategies. The fact that they could—already earlier—distinguish between surface level and deep level example elaboration could be an ‘indicator’ for germane metacognitive load. Some learners are capable of coping with the added mental load caused by the metacognitive control over the processing activity. In their results they could state: “Active meta-cognitive and deep cognitive example elaboration paid off especially when learners had to cope with more complex, far transfer tasks.” They also could conclude “that intensive metacognitive elaboration is related to higher mental effort.” This reinforces our idea that within germane cognitive load, we can distinguish between cognitive load related to the processing and storage of the schemas, next to cognitive load related to metacognitive monitoring of the latter activities. Secondly, the authors introduce the measure “Tolerance of ambiguity”.

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This concept is clearly related to the ‘metacognitive experiences’ that are mentioned by Flavell (1987, p. 22–25). The results of the study of Stark et al. show the interrelation between the two concepts: “It seems to be mainly the intensive meta-cognitive control of learning processes which is fostered by tolerance of ambiguity.”. The “illusions of understanding” they state in learners with poor results, seem to show how prior knowledge plays an intervening role in the possible impact of metacognitive control of the learning process.

The research of van Gerven, Paas and Schmidt, presented in this issue, can be approached from a different perspective when we adopt the concept of ‘meta-cognitive load’. The question is whether age in adults—affecting working memory capacity, lower processing speed, etc.—does also affect the monitoring abilities of their learning processes. We can question whether—next to paying attention to the presentation format of information—fostering monitoring processes can reduce meta-cognitive load in adults. Future research could contrast this approach to the traditional CLT-way of working especially upon the external representation format of information.

The contribution of Van Bruggen, Kirschner and Jochems in this issue can also be related to meta-cognitive load. The fact that learners work actively on external representations and that they have to ‘share’ these representations, can be considered as an invocation of an explicit monitoring activity, thus reducing meta-cognitive load of the learning activity.

A last remark is related to a potential methodological problem. In line with the remarks of Van Merriënboer, De Croock, Schuurman and Paas, we also expect that ‘measuring’ germane meta-cognitive load might be difficult.

225 **3. The position of prior knowledge in CLT**

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Kirschner—in his introductory article—rightly questions the role and position of prior knowledge. Since prior knowledge is considered as the clearest determinant of learning (Ausubel & Novak, 1978; Dochy, 1990) it is strange that CLT does not—explicitly—account for the role of prior knowledge. Consequently, in the research presented in this issue we now and then perceive minimal attention attached to prior knowledge. In the study of Van Merriënboer, De Croock, Schuurman en Paas (experiment 3) we see e.g., that students of different age levels are involved. This variable is not considered in the study (age levels = educational levels).

However, the study of Stark, Mandl, Gruber and Renkl (this issue) takes prior knowledge into account, but does not update the CL conceptual framework with this concept. But, earlier research results of Stark (1999) did already offer important ideas to update CL Theory; “metacognitive statements were based on problems of understanding due to lack of prior knowledge.”.

In our conception, prior knowledge can easily be integrated in CL Theory when we consider schema theory. High levels of prior knowledge imply that schemas are readily available in long term memory that can easily be retrieved into short term memory. These schemas serve as advance organizers that help to interpret sensory information and link it (organize) to the existing schema and/or schema elements.

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The available schemas therefore reduce the cognitive load since elements in LTM can be readily manipulated and stored.

A number of researches in this issue ground this assumption. The study of Pollock, Chandler and Sweller is of direct relevance. They state that as long as there are no rudimentary schemas (prior knowledge) available in LTM, learning will hardly take place because of the too high mental load. Their instructional approach fosters the construction of basic schemata (isolated-interacting elements method of instruction). Only after this phase, students are presented with complex problems and prior knowledge can be activated. This research ground—from another perspective—the taxonomic nature of types and levels of knowledge (cf. Bloom, De Block, etc).

The study of Mayer and Moreno presents an updated representation of CLT in which prior knowledge is positioned. Their figure 2, clearly resembles our Fig. 1 since it also stresses the contribution of prior knowledge in the construction of the schemas.

4. Concluding remarks

A number of issues remain to be discussed in relation to the articles in this special issue. A first one is e.g., whether all contributors to this special issue share the

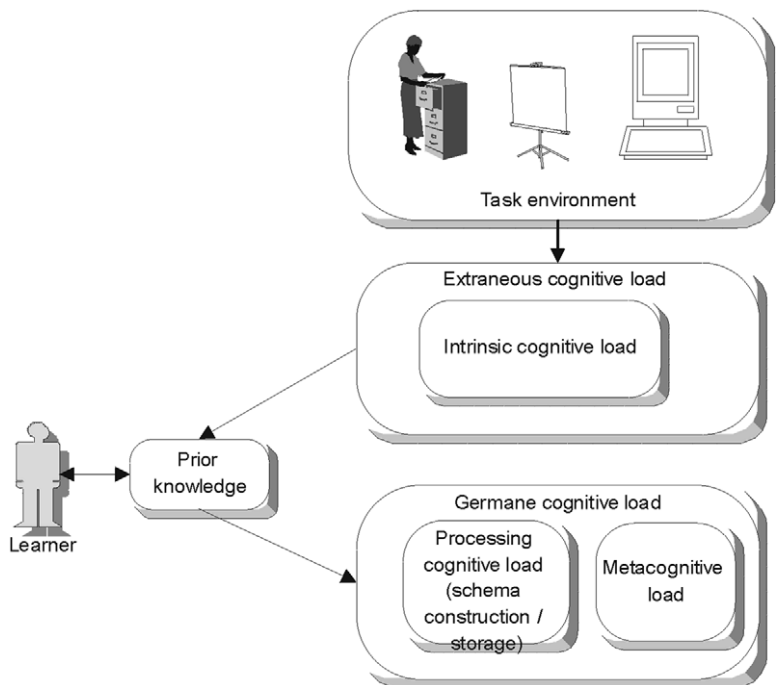


Fig. 1. An updated model for CLT. Positioning metacognitive load in the conceptual framework of current cognitive load theory.

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orientation towards competency-based education as suggested in the introduction of Kirschner. Other issues are related to: the way CLT deals with individual differences; the knowledge domains and types of knowledge considered; etc. But, as was stated in our introduction, we did not have the intention to cover all issues in this commentary. Our focus was especially on an attempt to update Cognitive Load Theory with the insight given us by the results of the researches reported here.

We focused first of all especially on the link between CLT and constructivist learning. Nowadays, it is fashionable to present the constructivist theory as a guiding theory for instructional design. But, what does this mean? How can we describe, explain predict, constructivist learning? As we have suggested CLT offers a theoretical grounding for certain constructivist principles.

Secondly, we focused on a possible extension of CL Theory to incorporate more explicitly metacognitive knowledge. We suggest—building on the research evidence presented here—that we are able to specify within germane cognitive load a subset of met cognitive load.

Thirdly, we attempted to position prior knowledge in the frame of reference of cognitive load theory. Multiple evidence was found to update the CLT model with this concept.

As a concluding remark, we can state that this issue offers a rich panorama of CLT-related research and theoretical work. But, what remains to be done is the continuous feedback of research findings to the original theory. Future research might benefit from these attempts. It also helps to consider cognitive load theory not only as a plug-in theory for specific issues. This integrative orientation helps to build up a generic validated and research-based cognitivist learning theory.

5. Uncited References

Buzan, 1995; Chi et al., 1989; Dochy, 1992; Schwarz & Reisberg, 1991; Valcke, 2000

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