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Cognitive Load Theory and its application in the classroom

Cognitive Load Theory (CLT) has recently become 'The Next Big Thing' in teaching. Dylan Wiliam tweeted on 26 January 2017 that he had 'come to the conclusion Sweller's Cognitive Load Theory is the single most important thing for teachers to know.' This is an emphatic statement and it is important to consider the implications. As teachers, there are huge demands on our time, so when considering a new strategy it is essential to evaluate the evidence.

CLT, first researched by Sweller (Sweller, 1998) towards in the late 1980s, is based around the idea that our working memory – the part of our mind that processes what we are currently doing – can only deal with a limited amount of information at one time. Reif's (Reif, 2010) description of cognitive load is extremely useful: 'The cognitive load involved in a task is the cognitive effort (or amount of information processing) required by a person to perform this task.' There are a number of excellent resources freely available online that explain CLT (see Paas et al. (Paas et al., 2003) for a useful overview), so we will only touch on the foundations of the theory here that will be useful for the rest of the article.

The theory identifies three different forms of cognitive load:

- Intrinsic cognitive load: the inherent difficulty of the material itself, which can be influenced by prior knowledge of the topic
- Extraneous cognitive load: the load generated by the way the material is presented and which does not aid learning
- Germane cognitive load: the elements that aid information processing and contribute to the development of 'schemas'.

CLT suggests that if the cognitive load exceeds our processing capacity, we will struggle to complete the activity successfully. In summarising CLT, De Jong (De Jong, 2010) states that 'cognitive load theory asserts that learning is hampered when working memory capacity is exceeded in a learning task'.

Working memory should be seen as short term and finite, whereas long-term memory can be seen as infinite. The aim should be to move knowledge to long-term memory because when a student is exposed to new material, they can draw on this previous knowledge and the cognitive load is reduced. However, if subject knowledge is incomplete, the student is unable to fall back on the long-term memory and the working memory becomes overloaded, leading to working memory failures.

According to Gathercole and Alloway (Gathercole and Alloway, 2007), indications of working memory failures include:

- incomplete recall
- failing to follow instructions
- place-keeping errors
- task abandonment.

Of course, there are many other reasons for these that are not related to CLT; however, if teachers understand how this theory applies to their classroom, they can plan their lessons in a way that takes into account cognitive load.

Reducing cognitive load

Intrinsic cognitive load can be reduced by breaking down the subject content, sequencing the delivery so that sub-tasks are taught individually before being explained together as a whole. The idea is to not overwhelm a student too early on in the introduction of new work. Extraneous cognitive load can be reduced by the way in which instructions are presented. We make sense of new material by referencing schema or mental models of pre-existing knowledge. Lack of clarity in instruction puts too high a load on the working memory, and so too much time is spent problem-solving the instructions as opposed to new schema formation. For example, lessons that use PowerPoint with excessive writing and the teacher talking at the same time, can inadvertently generate excessive cognitive load and lead to working memory failures. Chandler and Sweller (Chandler and Sweller, 1991) write that 'Cognitive Load Theory suggests that effective instructional material facilitates learning by directing cognitive resources towards activities that are relevant to learning.'

Introducing ideas within a topic

Van Merriënboer et al. (Van Merriënboer et al., 2003) recommend using simple-to-complex sequencing to try to reduce cognitive load. They advise starting with worked-out examples (where a full solution is shown, which students then have to apply to a new question), then moving into completion assignments (where a partial solution is given and they have to complete it themselves), and then moving to conventional tasks, where they are simply given the question. This acts as a form of scaffolding, which helps students to learn independently, without necessarily needing the help of their teacher for each stage.
Renkl and Atkinson (Renkl and Atkinson, 2003) further investigated this fading form of scaffolding. They suggested that moving through activities sequentially could reduce intrinsic load, as learners will have already mastered some of the knowledge they need to work out a solution in an earlier skill stage. Therefore, their research recommends beginning with a model (a complete example), gradually removing completed steps, which the learner will have to complete independently, and finally leaving just the to-be-solved problem.

These principles can be readily applied in the classroom by beginning with a model answer, then providing a writing frame/structure with a lot of information, followed by a writing frame/structure with less information, then finally a question that learners must complete independently without a writing frame. It is worth, though, being aware of the 'expertise reversal effect' suggested by Kalyuga et al. (Kalyuga et al., 2003), whereby if you continue to provide worked-out examples for experts, their usefulness is significantly reduced. Cognitive load theorists suggest this is because worked-out examples contain information that an expert could work out for themselves, making it redundant and therefore extraneous cognitive load rather than useful germane cognitive load.

Presenting information to minimise cognitive load

Chandler and Sweller (Chandler and Sweller, 1992) found evidence of the split-attention effect. This occurs when different sources of information discussing the same topic are separated by time or space, such as a diagram with a key that corresponds to separate text next to it. When information is presented in this way, it is left to the learner to attempt to amalgamate it, which generates extraneous cognitive load. Therefore, it is recommended that if one of the sources adds nothing new, it should be eliminated. However, if it is essential to include both sources, they should ideally be physically integrated (e.g. texts and diagrams combined). This way, extraneous cognitive load is reduced and working memory capacity can be used for intrinsic and germane cognitive load instead.

A word of caution

There are, of course, issues with CLT. Reif (Reif, 2010) writes that if cognitive load is reduced too much, 'the entire learning process would consist of too many small steps – and would thus become unduly fragmented and long'. There are also issues to do with the hypothesis being unfalsifiable. Doug Holton (Holton, 2009) points out that it is difficult to measure cognitive load, and therefore difficult to generate evidence to prove the theory.
An important question, though, is whether it is useful in the classroom. Ashman (Ashman, 2017) has explained that an understanding of CLT changed his maths teaching, and offers the following four examples:

1. I don't read out my slides – avoid simultaneous oral and text presentation
2. Break it down, further – pause for practice between individual problem types (this leads directly into number 3)
3. Example-problem pairs – give a worked example alongside an almost identical question
4. Stop after five minutes – advise students never to spend more than five minutes trying to solve a homework problem

So is CLT the single most important thing for a teacher to know? Perhaps not – it is a bold claim. But, if used correctly, it can improve teacher instruction, which is an important variable in the complex classroom environment.

References

Ashman G (2017) Four ways cognitive load theory has changed my teaching. Available at: https://gregashman.wordpress.com/2017/05/13/four-ways-cognitive-load-theory-has-changed-my-teaching%EF%BB%BF/ (accessed 25 July 2017).

Chandler P and Sweller J (1991) Cognitive Load Theory and the format of instruction. *Cognition and Instruction* 8(4): 293–332.

Chandler P and Sweller J (1992) The split-attention effect as a factor in the design of instruction. *British Journal of Educational Psychology* (62): 233–246.

De Jong T (2010) Cognitive Load Theory, educational research, and instructional design: Some food for thought. *Instructional Science* 38(2): 105–134.

Gathercole S and Alloway T (2007) Understanding working memory. A classroom guide. Harcourt Assessment. Available at: https://www.mrc-cbu.cam.ac.uk/wp-content/uploads/2013/01/WM-classroom-guide.pdf (accessed 11 July 2017).

Holton D (2009) Cognitive Load Theory: Failure? Available at: https://edtechdev.wordpress.com/2009/11/16/cognitive-load-theory-failure/ (accessed 25 July 2017).

Kalyuga S, Ayres P, Chandler P, et al. (2003) The expertise reversal effect. *Educational Psychologist* 38(1): 23–31.

Paas F, Renkl A and Sweller J (2003) Cognitive Load Theory and instructional design: Recent developments. *Educational Psychologist* 38(1): 1–4.

Reif F (2010) *Applying Cognitive Science to Education. Thinking and Learning in Scientific and Other Complex Domains*. Cambridge, MA: The MIT Press.

Renkl A and Atkinson R (2003) Structuring the transition from example study to problem solving in cognitive skill acquisition: A cognitive load perspective. *Educational Psychologist* 38(1): 15–22.

Sweller J (1998) Cognitive load during problem solving: Effects on learning. *Cognitive Science* (12): 257–285.

Van Merriënboer J, Kirschner P and Kester L (2003) Taking the load off a learner's mind: Instructional design for complex learning. *Educational Psychologist* 38(1): 5–13.