Cognitive Load Theory Updated; 20 Years On – Our Cognitive Architecture

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Cognitive Load Theory is increasingly influencing people's thinking and hopefully will also influence their approach to teaching. At its heart, it is a theory about instructional (teaching) design. I find it useful for the classroom; it chimes with me as an ex-Science Teacher.

Sweller et al (2019) updated paper, *Cognitive Architecture and Instructional Design: 20 Years Later* is an interesting read. I wouldn't describe it as light reading though others might; it depends how expert you are in the field.

The basic proposition of Cognitive Load Theory is: if our teaching aligns with how our pupils' cognitive architecture is designed then learning will be enhanced. It is based on the idea that we have a working memory that can hold a limited amount of information for a limited time and an unlimited long term memory. The retention and connection of information in the long term memory transforms our ability to function as this overcomes the limits of our working memory. The challenge is how to acquire increasing amounts of useful information in our long term memory and access it readily when needed.

For people familiar with the original work the three different types of cognitive load – intrinsic (related to the complexity of the material being studied and expertise of the learner); extraneous (how the information is presented) and germane (the working memory committed to the learning) – has been amended with the intrinsic and germane working load now considered to be *"closely intertwined"* rather than two separate summative elements.

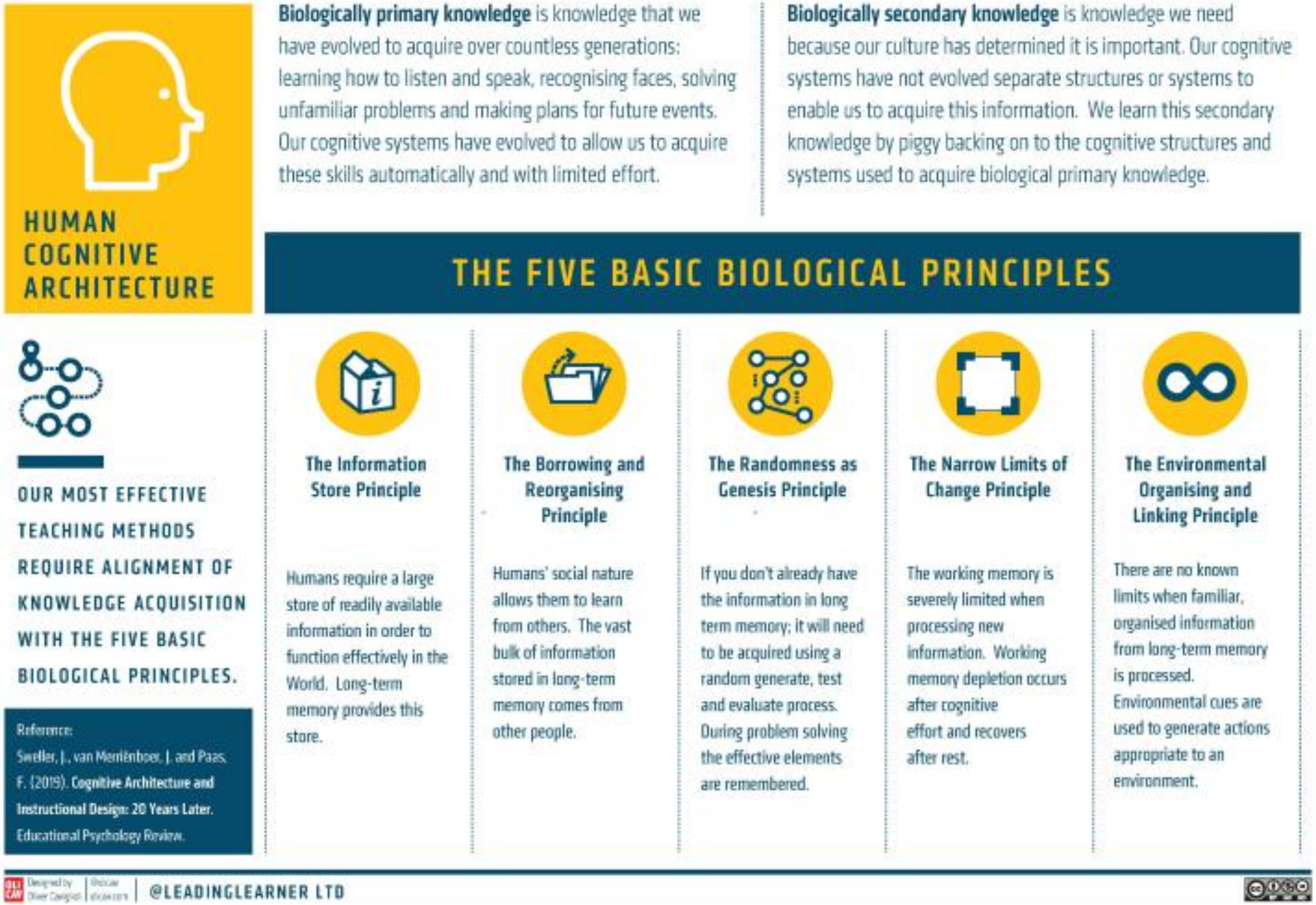
Human Cognitive Architecture

Sweller et al (2019) have developed aspects of their theory using advances in knowledge in Evolutionary Psychology. *Biologically primary knowledge is knowledge that we have evolved to acquire over countless generations:* learning how to listen and speak, recognising faces, solving unfamiliar problems and making plans for future events. *Our cognitive systems have evolved to allow us to acquire these skills automatically and with limited effort.*

The Five Basic Biological Principles of Cognitive Architecture
The Information Store Principle Humans require a large store of readily available information in order to function effectively in the World. Long-term memory provides this store.
The Borrowing and Reorganising Principle Humans' social nature allows them to learn from others. The vast bulk of information stored in long-term memory comes from other people.
The Randomness as Genesis Principle If you don't already have the information in long term memory; it will need to be acquired using a random generate, test and evaluate process. During problem solving the effective elements are remembered.
The Narrow Limits of Change Principle The working memory is severely limited when processing new information. Working memory depletion occurs after cognitive effort and recovers after rest.
The Environmental Organising and Linking Principle There are no known limits when familiar, organised information from long-term memory is processed. Environmental cues are used to generate actions appropriate to an environment.

Reference: Sweller, J., van Merriënboer, J. and Paas, F. (2019). Cognitive Architecture and Instructional Design: 20 Years Later. *Educational Psychology Review*.

Biologically secondary knowledge is knowledge we need because our culture has determined it is important. Our cognitive systems have not evolved separate structures or systems to enable us to acquire this information. *We learn this secondary knowledge by piggy backing on to the cognitive structures and systems used to acquire biological primary knowledge.* Our most effective teaching methods require alignment of knowledge acquisition with the five basic biological principles.



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Next post – [Cognitive Load Theory Updated; 20 Years On – Implications for Teachers & Teaching]

Reference:

Sweller, J., van Merriënboer, J. and Paas, F. (2019). Cognitive Architecture and Instructional Design: 20 Years Later. *Educational Psychology Review*. (Sweller2019_Article_CognitiveArchitectureAndInstru)

Cognitive Load Theory Updated; 20 Years On – Implications for Teachers and Teaching

This is the second part of a post; the first part is: Cognitive Load Theory Updated; 20 Years On – Our Cognitive Architecture (with a downloadable resource by Oliver Caviglioli – see below).

Twenty years ago a number of principles and strategies were developed, as part of Cognitive Load Theory, aimed at reducing the extraneous cognitive load when teaching. It's important to note that these are based on the premise that the information is new to the pupils (they are novices) and the information is complex (it has high element interactivity). Where this is less true then the theory is less applicable; the limits of working memory are unlikely to be reached.

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Table 1 Timeline of major cognitive load effects before and after 1998

Effect		First publication naming the effect	Description
Goal-free effect	1982	Sweller and Levine (1982). Effects of goal specificity on means-ends analysis and learning. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 8, 463–474.	Replace conventional tasks with goal-free tasks that provide learners with a non-specific goal.
Worked example effect	1985	Sweller and Cooper (1985). The use of worked examples as a substitute for problem solving in learning algebra. *Cognition and Instruction*, 2, 59–89.	Replace conventional tasks with worked examples that provide learners with a solution they must carefully study.
Completion problem effect	1987	van Merriënboer and Krammer (1987). Instructional strategies and tactics for the design of introductory computer programming courses in high school. *Instructional Science*, 16, 251–285.	Replace conventional tasks with completion tasks that provide learners with a partial solution they must complete.
Split-attention effect	1988	Tarmizi and Sweller (1988). Guidance during mathematical problem solving. *Journal of Educational Psychology*, 80, 424–436.	Replace multiple sources of information, distributed either in space (spatial split attention) or time (temporal split attention), with one integrated source of information.
Redundancy effect	1991	Chandler and Sweller (1991). Cognitive load theory and the format of instruction. *Cognition and Instruction*, 8, 293–332.	Replace multiple sources of information that are self-contained (i.e. they can be understood on their own) with one source of information.
Compound Element interactivity effect	1994	Sweller (1994). Cognitive load theory, learning difficulty and instructional design. *Learning and Instruction*, 4, 295–312.	Cognitive load effects that are found for high element interactivity materials are typically not found for low element interactivity materials. Actually, cognitive load theory is only relevant for complex learning.
Variability effect	1994	Paas and van Merriënboer (1994a). Variability of worked examples and transfer of geometrical problem solving skills: a cognitive load approach. *Journal of Educational Psychology*, *86*, 122–133.	Replace a series of tasks with similar surface features with a series of tasks that differ from one another on all dimensions on which tasks differ in the real world.
Modality effect	1995	Mousavi et al. (1995). Reducing cognitive load by mixing auditory and visual presentation modes. *Journal of Educational Psychology*, 87, 319–334.	Replace a written explanatory text and another source of visual information (unimodal) with a spoken explanatory text and the visual source of information (multimodal).
Publication of the 1998 article cognitive architecture and instructional design			
Self-explanation effect	1998	Renkl et al. (1998). Learning from worked-out examples: the effects of example variability and elicited self-explanations. *Contemporary Educational Psychology*, 32, 90–108.	Replace separate worked examples or completion tasks with enriched ones containing prompts, asking learners to self-explain the given information.

Educational Psychology Review

Taken from Sweller, J., van Merriënboer, J. and Paas, F. (2019). Cognitive Architecture and Instructional Design: 20 Years Later. Educational Psychology Review.

Two key ideas to understand when looking at the implications of Cognitive Load Theory on teaching are:

Expertise Reversal Effect – As pupils become more expert, what starts off as multiple interacting elements of knowledge begin to be organised and linked together in a relational way as ideas and these in turn into larger concepts. The effects described in the table below benefit novices; as expertise (conceptual understanding increases) the effects disappear or are even reversed.

Guidance Fading Effect – Over the course of an extended programme of learning pupils' expertise within a particular domain should increase. As it does, information and activities that are effective for novices, at the beginning of a course of study, become a distraction and place an unnecessary extraneous cognitive load on more expert learners.

Cognitive Load Theory 2.0 – Implications for Instruction & Course Design – PDF (Downloadable)

In the graphic above I have suggested a sequence for the various effects (going from left to right) as pupils gain expertise (knowledge). It is however important to remember that the effects all appertain to novice learners or those at the beginning of a longer programme of study.

In terms of tasks: giving pupils fully worked examples (the **Worked Example Effect**) to show how a solution could be reached; followed by the use of partial solutions (the **Completion Problem Effect**) in which pupils have to complete the missing elements and tasks that do not have a specified end point (goal) with one that is goal free (the **Goal Free Effect**) is a reasonable sequence linked to their growing expertise. The **Isolated Elements Effect**, common sense to experienced teachers, proposes breaking down a complex piece of learning into smaller sequential information/tasks that can be taught separately. The **Variability Effect** increases the intrinsic cognitive load potential, so as long as the total cognitive load stays within limits, the variable problems presented allows pupils to identify similar relevant features (general principles) that can be applied.

There is also a place for collaborative working due to the aptly named **Collective Working Memory Effect**; collaboration increases the overall working memory and information available in long term memory to the group, to solve a problem. My word of caution here would be that too often groups of pupils are asked to work on tasks that are too simple; they would be better off completing them individually. Make sure the task given a group is sufficiently challenging and complex; it links well to problem solving approaches.

There are a series of effects that I'd tend to group under metacognition or self-regulation: The **Self-Explanation Effect** utilises worked example (see above) with pupils provided with self-explanation prompts which require them to explain their approach. This could alternatively be approached using The **Imagination Effect** requires pupils to imagine or mentally rehearse a concept or process, for example, the steps to solving a problem. The latter is more suitable to pupils as they gain expertise; at a novice stage the imagination exercise is likely to overload working memory.

The **Self-Management Effect** is built on the assumption that pupils taught to apply Cognitive Load Theory principles themselves – for example, to redesign or design materials which are poorly produced – can manage their own cognitive load. Teachers can explicitly teach the principles and model good practice. For example, ways of presenting materials that would help reduce the overall cognitive load are: replace multiple sources of information split over space (eg. different pages of a book) or time with one integrated resource (**Split-Attention Effect**) and replace multiple sources of the same information with one (**Redundancy Effect**). The **Modality Effect** suggests the replacement of two visual sources of information (unimodal) with one visual and one auditory (multimodal).

"The modality effect is based on the assumption that working memory can be subdivided into partially independent processors, one dealing with verbal materials based on an auditory working memory and one dealing with diagrammatic/pictorial information based on a visual working memory. Consequently, effective working memory capacity can be increased by using both visual and auditory working memory rather than either processor alone."

Reference:

Sweller, J., van Merriënboer, J. and Paas, F. (2019). Cognitive Architecture and Instructional Design: 20 Years Later. *Educational Psychology Review*. (Sweller2019_Article_CognitiveArchitectureAndInstru)