Cognitive Load Theory, Learning Difficulty, and Instructional Design *(John Sweller, 1994)*

In order to learn, information must pass through and be processed by the working memory. If a learner were to process every bit of information just using the working memory, this would lead to a cognitive over-load and little information would be retained. To ease cognitive load, the Long-Term Memory acts as executive in aiding the information passed through the working memory. This is done via schema acquisition and automation. Both of these help to significantly reduce working memory load. Schemas help by chunking information in the long-term memory, which then comes back to what is being processed in the working memory in order to apply the new data to an already existing schema, therefore reducing the processing. Information that has been learned and practiced over a long period of time can become automatic. Automation means that extraneous cognitive load is decreased because load for data processed automatically is not required.

When students are presented with novel problems schemas and automation are not applicable. In these cases a strategy such as a Means-End Strategy is required. Here, differences between each problem and the goal state are extracted and then problem solving operators are found, which helps to reduce cognitive load. This helps to find the goal by finding relationships and narrow the processing to like-information. The article goes on to discuss element interaction. When information can be learned in isolation it is considered to have low element interaction, which, in most cases, eases cognitive load by decreasing the amount needed to be processed. High element interaction occurs when information cannot be learned without "simultaneously learning the connections between a large number of elements."

The article also touches on Intrinsic and Extraneous Cognitive Load. Extraneous cognitive load can be avoided by considering the above information. Intrinsic cognitive load is fixed and designs must be shaped to consider the learner's current situation. In design, high element interactivity should be avoided and presentation should focus on schema acquisition and adjustment.

Cambridge Handbook of Multimedia Design – Implications of Cognitive Load Theory for Multimedia Learning *(John Sweller)*

The article starts out by stating that there is "no logical central executive available when required to organize novel information." (p.19) We must, therefore, consider human cognitive architecture in order to avoid a random effectiveness of instructional designs. Our long-term memory, which has been passed down through the generations of evolution, "heavily determines our cognitive lives." (p.20) Sweller states that "Learning is defined as an alteration in long-term memory." (p.20) Therefore, instruction should focus on altering long-term memory. Much of our knowledge of long-term memory happens to come from the game of chess, where it was learned, much to people's surprise, that expert chess players had images of board configurations from real games stored in their long-term memories. Instrctional design aims to assist learners in forming pathways to a solution in a similar way that expert chess players use board configurations to strategize. There are two methods Sweller discusses, Rote Learning and Learning for Understanding, both of which have an effect on long-term memory. "Rote learning occurs when some connections between elements occur but other, essential connections, are omitted." (p.20) This is similar, it seems, to the information gleaned from schemas when the working memory solicits data from the long-term memory. Schemas are important here as a way of chunking information into countless numbers of schemas that are stored in the long-term memory. Schemas are stored by pictorial, verbal, written, or spoken forms. Using schemas cuts down on cognitive load by allowing information to be processed automatically. This is important because working memory is only able to hold a small amount of information and for a limited amount of time (according to Miller, working memory can only hold seven elements of information). Therefore, instruction should aim to build and alter schemas. (If working memory were to be larger this could present problems in how many possibly combinations of schemas need to be processed in order to find the correct solution, see page 22.) We must develop instructional methods to overcome the limitations of working memory. "Instructional guidance that provides a substitute for the missing schemas and allows learners to develop their own schemas without engaging in the difficult… process…" (p.26), this provides more basis for developing and enhancing schemas and focusing instructional design around them in order to cut cognitive load. If it is ignored then learning may suffer.

Working memory is divided into several processors: coordinating central executive and two subsystems – a visuo-spatial sketchpad and a phonological loop. Incorporating both subsystems leads to better acquisition. This can be done by means of multimedia learning. One thing to consider with multimedia learning though is split-attention and the split-attention effect. As well, there are: Modality Effect, Redundancy Effect, Expertise Reversal Effect, and Intrinsic Cognitive Load to consider.

Cambridge Handbook of Multi-Media Learning – The Split Attention Principle in Multimedia Learning *(Paul Ayres & John Sweller)*

The Split-Attention Principle: "when designing instruction… it is important to avoid formats that require learners to split attention between… multiple sources of information." (p.135) This increases cognitive load and decreases learning effectiveness. Connected information must be presented together in order to avoid this. This occurs often when using multimedia. Learners must work to integrate many bits of data. It is most commonly associated with mathematical diagrams and their equations – presenting the two together or separately. If diagrams and text are integrated then cognitive load is decreased because learners have all of the required information presented together. This changes, though, if some information is not required. Studies done by Sweller, Chandler, Tierney, and Cooper (1990) found that "initial instructions presented in an integrated format were superior to the same instructions presented in a split-attention format." (p.138) It is also applicable in non-mathematical circumstances, such as biology lessons, language learning, and instruction manuals. Again, issues come up when integrating formats of data lead to redundancy. This also goes back to element interactivity, discussed in the other articles. "Materials low in element interactivity are easy to learn because they keep working memory demands to a minimum." (p.142) This means that combining bits of information that must be learned simultaneously is likely to decrease cognitive load, whereas like-information could lead to redundancy and an increase of cognitive load.

Continuing on multimedia, Mayer's research concluded that with films shown to college students, those who received the visual and auditory materials either simultaneously or the visuals 7 seconds before the voice-overs did significantly better on recall tests than those who received the visuals 14 or 21 seconds before or who received the visuals after the voice-overs. The results were repeated in studies done by Mayer and Anderson (1991). Viewing the two forms of media concurrently increased learning effectiveness. In incorporating this into instructional design, one should note that integrating information is key to reducing extraneous cognitive load (although it is important to ensure that redundancy is avoided).

Cambridge Handbook in Multimedia Learning – The Redundancy Principle in Multimedia Learning *(John Sweller)*

The Redundancy Principle is defined as: having redundant material that "interferes with rather than facilitates learning" (p.159).

Sweller starts out by saying that the Redundancy effect has been discovered and forgotten over the course of its history many times. It is important to avoid redundant information because of the extra processing time the working memory requires in order to remove it. Rather than inhancing learning, redundant information inhibits it. Cognitive Load Theory is used to explain the effect that including redundant information can have, considering the limitations of working memory. Due to working memory's limited capacity and duration, having too much information in one space, which requires more processing time, is the same as incorparting the split-attention effect, etc. Working memory resources will be required to sift through all of the information presented. In research conducted by Miller, it was found that presenting children with the word "cow" along with a picture of a cow and the audio of the word cow required more processing and was less effective than just presenting them with the written word and the audio. In this example, it should be noted that the child most likely already knows the definition of "cow" and that learning the spelling is different than learning the vocabulary. Reading is learning the letters and their sounds and how they go together, learning vocabulary is learning the meanings of full words. Still, as Sweller points out, many texts employed by teachers still use all three forms together.

If the information presented has all of the required data for the learner to understand the presented material, anything beyond that is excessive and should be avoided. Again, element interactivity is considered in such that too much information causes an increase in cognitive load. There is a correlation between avoiding redundancy and avoiding split-attention. One must, in instructional design, know what the relevant information is and how to integrate it without having it become redundant. This also depends on the expertise level of the learner. Someone who is an expert will not require as much explanatory information and what may be required for a novice becomes redundant for the expert. As well, if a novice is learning material that is presented separately from pertinent information, he/she may suffer from the split-attention effect. Redundant material must be eliminated but what is redundant must be determined based on the audience. Page 166 outlines several questions that should be asked when trying to determine whether or not information is redundant, such as, "Is the diagram intelligible in isolation?"