Cognitive load theory

In essence, cognitive load theory proposes that since working memory is limited, learners may be bombarded by information and, if the complexity of their instructional materials is not properly managed, this will result in a cognitive overload. This cognitive overload impairs schema acquisition, later resulting in a lower performance (Sweller, 1988).

Cognitive load theory had a theoretical precedence in the educational and psychological literature, well before Sweller's 1988 article (e.g. Beatty, 1977; Marsh, 1978). Even Baddeley and Hitch (1974) considered "concurrent memory load" but Sweller's cognitive load theory was the first to consider working memory, as it related to learning and the design of instruction.

When instructional designers develop instructional materials they intentionally choose a means of presenting information. Instructional strategies may vary depending on the content, but they range from organizational strategies, sequencing, cues, feedback, orienting or question techniques, but, may also include different types of media (Fleming & Levie, 1993). These instructional strategies have a variety of effects on learning, depending on the media and strategies being used to present instruction (Mousavi, Low, & Sweller, 1995; Sweller & Chandler, 1991; Sweller & Cooper, 1985). A fundamental claim of cognitive load theory is that these strategies are likely to be random in their effectiveness, unless they consider the underlying cognitive architecture of the learner during instruction (Clark, Nguyen, & Swelller, 2006).

Schema acquisition is the ultimate goal of cognitive load theory. Anderson's ACT framework proposes initial schema acquisition occurs by the development of schema-based production rules, but these production rules may be developed by one of two methods (Anderson, Fincham, & Douglass, 1997), either by developing these rules during practice or by studying examples. The second method (studying examples) is the most cognitively efficient method of instruction (Sweller & Chandler, 1985; Cooper and Sweller, 1987; Paas and van Merriënboer, 1993). This realization became one of the central tenets of cognitive load theory.

Once learners have acquired a schema, those patterns of behavior (schemas) may be practiced to promote skill automation (Anderson, 1982; Kalyuga, Ayres, Chandler, and Sweller, 2003; Shiffrin & Schneider, 1977; Sweller, 1993) but expertise occurs much later in the process, and is when a learner automates complex cognitive skills (Shiffrin & Schneider, 1977), usually via problem solving.

Types of cognitive load

Cognitive load theorists distinguish between three types of load: intrinsic, extraneous and germane cognitive load. Sweller and his associates clearly defined intrinsic cognitive load this way "Intrinsic load is the mental work imposed by the complexity of the content" (Clark, Nguyen, & Swelller, 2006, p. 9).

When Sweller (1993) first described intrinsic cognitive load he said "Intrinsic cognitive load is imposed by the basic characteristics of the information rather than by instructional design" (Sweller, 1993, p.6). Later, Sweller and his associates described two additional types of cognitive load that instructional designers may control, as they structure the manner in which instruction is presented (Sweller, van Merriënboer, & Paas, 1998). These two forms of cognitive load are associated with the presentation of instructional materials, extraneous cognitive load (Chandler & Sweller, 1991; Chandler & Sweller, 1992), and germane cognitive load (Sweller, Van Merriënboer, & Paas, 1998).

Sweller and his associates describe "extraneous cognitive load" as that load not inherent within the instruction, but is imposed by the instructional designer as they structure and present information (Chandler & Sweller, 1991; Chandler & Sweller, 1992). Extraneous cognitive load is a concern when intrinsic cognitive load is high (Paas, Renkl, & Sweller, 2003; Paas, Tuovinen, Tabbers, and Van Gerven, 2003). This is because intrinsic and extraneous load are additive, but when intrinsic load is low, the learner will probably have less trouble grasping the underlying content (Paas, Renkl, & Sweller, 2003), but instructional designers should always strive to limit cognitive load.

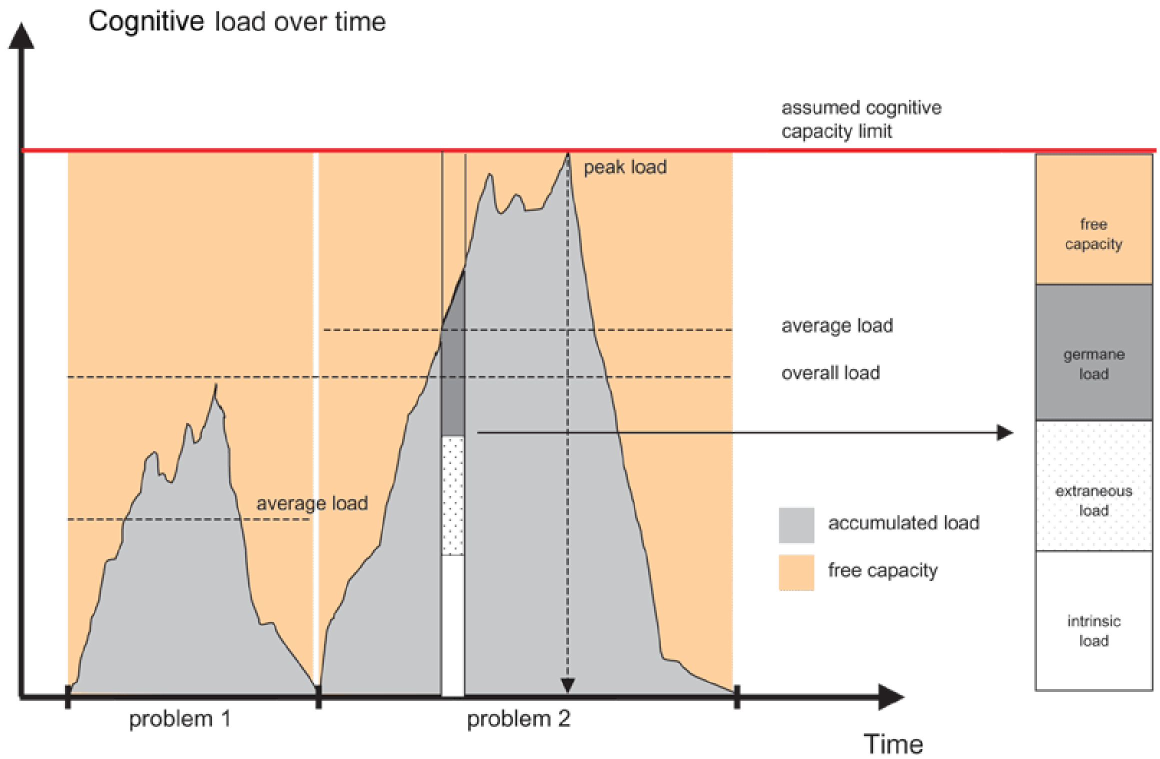

Figure 1. Cognitive load over time

Note: Adapted from Cognitive Load Measurement as a Means to Advance Cognitive Load Theory. by F. Paas, J.E. Tuovinen, H. Tabbers, and P. W. M. Van Gerven, 2003, Educational Psychologist, 38, p. 65

Finally the third type of cognitive load is germane (or relevant) load. This final type of cognitive load is that remaining free capacity in working memory, which may be redirected from extraneous load toward schema acquisition (Sweller et al., 1998). Next this discussion turns its attention toward the source of intrinsic cognitive load.

Element interactivity

Three types of cognitive load impact working memory over time (Paas et al, 2003) and certainly the amount of information a learner must process over a period of time is important, but the most important factor given instruction is the complexity of that information (Pollock, Chandler, & Sweller, 2002). According to Sweller and Chandler (1994), instructional content is composed of component parts or “elements;” and these elements may be said to “interact” if there is a relationship between them, thus raising the complexity of the instruction. Sweller and Chandler (1994) describe this phenomenon as “element interactivity.”

Van Merriënboer and Sweller (2005) describe element interactivity well, when they mention “Working memory must inevitably be limited in capacity when dealing with novel, unorganized information because as the number of elements that needs to be organized increases linearly, the number of possible combinations increases exponentially” (van Merriënboer & Sweller, 2005, p.149).

Sweller and Chandler (1994) described the intrinsic structure of information as "unalterable," Sweller and his associates later argued that even when the cognitive load of instruction is very high, instructional designers may artificially reduce the intrinsic load of instruction, by dividing a lesson into smaller pieces, reducing the intrinsic load of the overall lesson. Sweller describes these smaller pieces as "subschemas" (Clark, Nguyen, & Sweller, 2006). This method of dividing the presentation of material was first developed by Pollock, Chandler, and Sweller (2002).

However, this method of dividing a lesson into subschemas promotes learning at the expense of understanding, but as Sweller explains, they were never able to understand the full schema anyway (Clark, Nguyen, & Sweller, 2006). Thus Pollock, Chandler, and Sweller (2002) found that, if learners process the individual elements of instruction serially, rather than simultaneously, that they were able to process that instruction, to be able to recombine these individual subschemas, to eventually understand the whole problem.

It should be noted these researchers were not the first to suggest breaking instructional materials down into its component parts. Gagné recognized this phenomenon in the 1960s (Gagné & Paradise, 1961; Gagné, 1968). However, it is important to realize that Sweller and his associates not only recommended this method of instruction, but were also able to explain why Gagné's learning hierarchies are an effective means of presenting instruction.

Recommendations of cognitive load theory

Because working memory resources are limited, novices may become distracted by irrelevant aspects of a problem, to make errors during problem solving (Sweller, 1988). Thus cognitive load theorists recommend learners first, study worked examples to promote schema acquisition; this strategy is recommended as opposed to allowing learners to learn through problem solving (Cooper & Sweller, 1987; Sweller, 1988; Sweller & Cooper, 1985). Later as they gain expertise, some researchers suggest fading worked examples (Renkl, Atkinson, & Maier, 2000; Renkl, Atkinson, Maier, and Staley, 2002) to replace problems with partially-completed problems (van Merriënboer & de Croock, 1992) to eventually practice by solving whole problems to facilitate skill automation (Kalyuga, Ayres, Chandler, and Sweller, 2003).

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