Teaching tips based on Cognitive Load Theory

Cognitive Load Theory (CLT) suggests that learning occurs most efficiently when instruction is designed according to our knowledge of cognitive architecture. According to the CLT, learners have a limited amount of working memory, which is the memory needed for conscious activities such as processing new information. In fact, working memory is likely limited to about seven items or elements of information at any one time (Miller, 1956). In contrast, learners have an unlimited amount of long-term memory, which provides a repository of permanent knowledge and skills. Information elements are stored in long-term memory as schemata, which hold large quantities of information but can be processed as a single unit in working memory (Sweller, 1994). As a learner acquires schemata, their performance progresses from slow and difficult to smooth and effortless because the information can be handled more efficiently by working memory, or used automatically, in the form of schemata.

Because learners have limited working memory, instruction should be designed to make the best use of this capacity without overloading it. Working memory load is affected by the complexity of the material (intrinsic CL) and the way the material is presented (extraneous and germane CL). When material is presented in a way that is useful in building schemata, cognitive load is considered germane (Sweller et al., 1998). In contrast, mental effort that is put forth but does not build schemata or interferes with schemata construction is considered extraneous CL. Thus, according to CLT, more learning can take place with the same mental effort when extraneous CL is shifted to germane CL. Although extraneous and germane CL cannot be directly measured, instructional approaches designed to efficiently build new schemata can result in better learning outcomes with equivalent or less mental effort (van Merrienboer et al., 2002).

Instructional approaches that aid in the efficient construction of new schemata are described for a variety of teaching scenarios in the following tips.

1) **Teaching problem-solving.** Solving novel problems requires significant working memory if schemata are not already in place. Rather than asking students to immediately solve problems from start to finish, instructors should begin by providing worked examples and then asking students to finish partially-completed problems. Worked examples and partially-completed problems help students build schemata so that less working memory is required to complete a problem independently from start to finish (Sweller et al., 1998).

2) **Designing instructional materials.** Instructional materials often include a combination of text, figures, and tables, as well as abbreviated terms. The process of searching for referenced items generates extraneous CL because the learner must hold information in working memory while searching for the associated referenced item. This effort devoted to mental integration is caused by the format of the material rather than the intrinsic complexity of the material and is termed the “split-attention” effect. The split attention effect can be reduced by physically integrating text and figures in instructional materials (Sweller et al., 1998). For example, when possible, information included in a figure caption should be placed in a legend or as labels in the figure itself.

3) **Delivering effective lectures.** Working memory is thought to consist of two subcomponents - one based on auditory working memory and one based on visual working memory (Baddeley, 1992). It is believed that working memory capacity can be increased by using both types of

working memory rather than either stream alone (Penney, 1989). Therefore, learning can take place more efficiently when information is presented in two modes – audio and visual. Furthermore, explanations are better understood when corresponding words and pictures are delivered simultaneously rather than separately, and when auditory explanations include few extraneous words and sounds (Mayer and Moreno, 2002). Finally, when using multiple modes of delivery, it is better to present visual aids (e.g., animation) and narration rather than visual aids, narration and on-screen text to avoid redundancy (Mayer and Moreno, 2002).

4) **Teaching laboratory procedures.** Laboratory procedures often involve many steps and are considered complex due to the many interacting elements that must be understood to acquire new schemata. Research suggests that a two-phase teaching approach, where basic steps or elements are first presented ("pre-training") and then their interactions are explained, can be more effective than explaining the elements and their interactions at once (Pollock et al., 2002). Instructors of laboratory courses can make use of the CLT by teaching students basic lab skills prior to explaining the full laboratory procedure.

The CLT provides guidelines for efficient instructional design. Limitations to working memory can be overcome by: constructing schemata, avoiding split attention and redundant information, using more than one presentation mode, and pre-training. These strategies can be incorporated into a variety of teaching scenarios to improve learning efficiency.

References

Baddeley, A.D. 1992. Working memory. Science 255: 556-559.

Mayer, R.E. and R. Moreno. 2002. Aids to computer-based multimedia learning. Learning and Instruction 12: 107-119.

Miller, G.A. 1956. The magical number seven, plus or minus two: some limits on our capacity for processing information. Psychological Review 63: 81-97.

Penney, C. 1989. Modality effects and the structure of short-term verbal memory. Memory and Cognition 17: 398-422.

Pollock, E., P. Chandler and J. Sweller. 2002. Assimilating complex information. Learning and Instruction 12: 61-86.

Sweller, J. 1994. Cognitive load theory, learning difficulty, and instructional design. Learning and Instruction 4: 295-312.

Sweller, J., J. van Merrienboer and F.G.W.C. Paas. 1998. Cognitive architecture and instructional design. Educational Psychology Review 10: 251-296.

Van Merrieboer, J.J.G., J.G. Schuurman, M.B.M. de Croock, and F.G.W.C. Paas. 2002. Redirecting learners' attention during training: effects on cognitive load, transfer test performance and training efficiency. Learning and Instruction 12: 11-37.

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