ISSN 2311-6080

USING THE COGNITIVE LOAD THEORY TO ASSIST IN THE DESIGN OF INSTRUCTION FOR THE UNIVERSITY LECTURE ROOM: SOME KEY LESSONS

Dr. Samuel Adaboh
Department of Education, Valley View University
OYIBI-ACCRA, GHANA

ABSTRACT

Stakeholders in higher education globally have become increasingly concerned as to whether products from universities and colleges are coming out with the knowledge, skills and competencies that prepare them for work and further education. Much research time have been devoted to exploring how students learn better and how instruction could be designed to facilitate this. This article offers a description of the cognitive load theory (CLT) and its relevance for instructional design and practice in the higher education environment. It attempts a summary of the salient aspects of the theory such as what cognitive load theory is, types of cognitive load, assumptions of CLT, instructional design and some useful ways CLT could be applied in the design of instruction and facilitates learning in the higher education environment. The paper takes the position that although CLT has recently been the subject of criticism for its lack of conceptual clarity (Schnotz & Kurshner, 2007) and methodological approaches (Gerjets, Scheiter, & Cierniak, 2009), it still holds immense relevance for teaching and learning in education. The fact that research is ongoing, especially its applicability in complex learning environments, should rather be a source of hope and encouragement to instructional developers and teachers who are increasingly looking for ways to improve learning at all levels, but particularly in higher education.

Keywords: Cognitive Load Theory, Schema, Instructional Design.

INTRODUCTION

The upsurge of interest in recent decades in education and training, and on the effectiveness and efficiency of various instructional design strategies has also led to considerable research in the field of cognitive theory. Stakeholders in education are not only advocating for measures to enable students learn better but also to be equipped with the ability to become critical thinkers. Critical thinking is essential in meeting the daily challenges of modern life, where individuals have to deal with unlimited amounts of information, complex problems, and rapid technological and social changes. Indeed, critical thinking ought to be the focus of education at all levels and the preoccupation of all educators (Angeli & Valanides, 2009). Cognitive load theory (CLT) which originated in the1980s has since expanded considerably in its examination of the structure of information and the cognitive architecture that allows learners to process that information (Paas, Renkel & Sweller, 2003). The importance of the construct of cognitive load to cognitive psychologist, educators and indeed instructional designers cannot be overemphasized.

COGNITIVELOAD THEORY

Cognitive load theory can be said to be an instructional model that came out from the field of cognitive science research. It is usually conceptualized as the extent to which cognitive resources are taken up by activities that facilitate learning (Quiroga, Crosby & Iding, 2004). It simply refers to the load on working memory during instruction and asserts that learning is impeded when the capacity of the working memory is exceeded in a learning task (De Jong, 2009).The fundamental principle of cognitive load theory is that the quality of instructional design, and consequently learning, will be greater if attention is paid to the role and limitations of working memory. The theory in essence offers a description of learning seeing it in terms of an information processing system. According to Cooper (1998), this system is made up of long-term memory, which stores knowledge and skills on a more-or-less permanent basis, and working memory, which performs the intellectual tasks associated with learning. Information may only be stored in long-term memory after first being dealt with by working memory. The fundamental principle of cognitive load theory is that the quality of instructional design will be greater if attention is paid to the role and limitations of working memory. The theory thus describes how the architecture of the brain has specific implications for the design of instruction. Kirschner (2002) discusses human cognitive architecture as made up of memory and schemas. This indeed is an affirmation of an earlier identification by Sweller, van Merrienboer and Paas (1998). These writers summarize the architecture as follows:

We have a limited working memory that deals with all conscious activities and an effectively unlimited long-term memory that can be used to store schemas of varying degrees of automaticity. Intellectual skill comes from the construction of large numbers of increasingly sophisticated schemas with high degrees of automaticity. Schemas both bring together multiple elements that can be treated as a single element and allow us to ignore myriads of irrelevant elements. Working memory capacity is freed, allowing processes to occur that otherwise would overburden working memory. Automated schemas both allow fluid performance on familiar aspects of tasks and—by freeing working memory capacity—permit levels of performance on unfamiliar aspects that otherwise might be quite impossible (p.258). One major assumption of the human working memory is that it has only a limited capacity (Kirschner, 2002). In the process of learning humans allocate most of their cognitive resources to such learning activity. The instructional format can result in an over load in the course of the learning process. The challenge then is to so design instruction as to reduce such external over load in order to make more cognitive capacity available for effective learning.

ASSUMPTIONS OF COGNITIVE LOAD THEORY

CLT has three underlying assumptions that explain how people learn (May & Moreno, 2003). These are the active processing assumption, the dual channel assumption, and the limited capacity assumption. The active processing assumption is predicated on the fact that the learner is actively engaged in the process of knowledge construction. This process involves attending to relevant material, organizing the material into a coherent structure and integrating this into existing knowledge. The dual knowledge assumption recognizes the duality of the cognitive processing of information. These are an auditory/verbal channel for processing auditory input and a visual/pictorial channel for handling pictorial and visual representations. The last assumption, the limited capacity assumption, recognizes the limited capacity of each channel in working memory. Although the debate over the exact limit of the working memory is still unresolved among cognitive scientists, the questions of its limited capacity as compared to the long term memory is not in doubt.

TYPES OF COGNITIVE LOAD

The cognitive load theory identifies three types of cognitive load-intrinsic cognitive load, germane cognitive load, and extraneous cognitive load. Intrinsic cognitive load refers to the amount of cognitive processing that is necessary for a learner to comprehend material. This depends on the number of information elements and their interactivity. For example, a beginning reader encountering a comprehension passage for the first time will have a high intrinsic cognitive load. This is because to understand a sentence, the learner will have to examine each word and how they relate to other words in each sentence. All these activity goes on simultaneously in the working memory. In other words this load is caused by task-intrinsic aspect of learning. In contrast to intrinsic load, extraneous or ineffective cognitive load is caused by the (ineffective) format of instruction. All information processing irrelevant to the goals of instruction represents extraneous load. When there is an unnecessarily high degree of element interactivity due to instructional format or when instructional activities are unrelated to schema acquisition then extraneous cognitive load can occur. The simple implication is that, all irrelevant cognitive activities should be eliminated, because they interfere with learning. In seeking to establish the relationship between the two types of cognitive load described above, Paas, Renkl & Sweller (2003) explain:

Extraneous cognitive load is primarily important when intrinsic cognitive load is high because the two forms of cognitive load are additive. If intrinsic cognitive load is low, levels of extraneous cognitive load may be less important because total cognitive load may not exceed working memory capacity. As a consequence, instructional designs intended to reduce cognitive load are primarily effective when element interactivity is high. When element interactivity is low, designs intended to reduce the load on working memory have little or no effect. (p. 2). The last form of cognitive load is germane or effective cognitive load. This type of load occurs with deep cognitive processing by the learner and is dedicated to the formation and automation of schema. This load is influenced by the instructional designer. This is because the manner in which information is presented to learners and the learning activities required of learners are factors relevant to levels of germane cognitive load (Paasetal., 2003). Unlike extraneous cognitive load which can interfere with learning, germane cognitive load rather enhances learning. In summing up the effect of these types of cognitive load on learning, one should note the three forms of cognitive load tend to be additive and that it is only after a base load is taken up by the intrinsic cognitive load that what is left of the working memory can be taken up by the extrenous and germane load (Paaset al. 2003). Emphasizing how learning occurs, Kalyuga (2007), explains that the learner needs to attend and process new information and establish connections between them, while integrating them with the available or existing knowledge base. This results in the building of new or modified knowledge structures.

INSTRUCTIONAL DESIGN

With this information the question that one may legitimately ask is; what is the new frontier of instructional design? Kirschner (2002) seems to answer this clearly by stating that:

An instructional design that results in unused working memory capacity because of a low intrinsic CL imposed by the instructional materials and/or low extraneous CL due to appropriate instructional procedures may be further improved by encouraging learners to engage in conscious cognitive processing that is directly relevant to schema construction. Clearly, this approach can only work if the total CL of the instructional design (intrinsic CL + extraneous CL + germane CL) is within working memory limits (p. 3). In order to examine some of the specific ways in which an understanding of cognitive load theory can enhance the design of suitable instruction, it will be pertinent to briefly define instructional design. Myriad definitions (Morrison, Ross, & Kemp, 2004; Smith & Ragan, 2005; Branch, 2008; Morrison, Ross, Kelman, & Kemp, 2011), have been proffered for instructional design that sees it variously as a science, discipline, reality and a process. In a simple and straightforward definition, Seels and Glasgow (1998), see instructional design “as a process of solving instructional or educational problems through systematic analysis based on the conditions of learning” (cited in Azimi & Fazelian, p. 526). Instructional designers are interested in understanding the mental processes that occur when spoken or written texts with or without static or animated pictures or graphs are presented to learners and how the displayed information can be adapted to the limitations of the cognitive system. The purpose of instructional design is to identify the outcomes of instruction, guide the development of instructional content (scope and sequence), and establish how instructional effectiveness will be evaluated.

USEFULNESS OF COGNITIVE LOAD THEORY

The usefulness of the cognitive load theory on the design of instruction could best be examined in the light of the effects of cognitive load. These effects have been identified as the split-attention effect, the redundancy effect, and the modality effect (Tamizi & Sweller, 1988; Chandler & Sweller, 1991; Mousavi, Low & Sweller, 1995).

i. The modality effect or principle refers to cognitive load learning. The modality effect can be explained based on the dual channel assumption, which states that visual and auditory materials are processed in two separate subsystems of working memory, each with a limited processing capacity. Using materials that combine textual and pictorial information, CLT researchers such as Mousavi, Low, and Sweller (1995) and Mayer and Moreno (1998) demonstrated superior learning outcomes for students who were taught via narration and pictures (i.e., auditory and visual presentation) as opposed to learners who were taught the same material via written text and pictures (i.e., visual-only presentation) (cited in Elliot, Beddow & Frey, 2009). The use of visual and auditory channels exposed learners to the use of the processing capacity of both channels. The implication here is that in the design of instruction, developers must develop text that will make use of auditory and visual channels in order to promote effective learning. It also implies that classroom teachers should not forget the superiority of learning through both channels and should factor that in the choice of materials in classroom instruction.

ii. The redundancy effect says when the same information is presented more than once the multiple processing is negative for comprehension since it increases external cognitive load. Whereas this can be beneficial to novices the performance of experts can be impaired. Such excessive material may include word-for- word narration of text and adding text or audio explanations to self-explanatory visuals. The idea is that it is important to avoid information overload so as to minimize the extraneous cognitive load. “The redundancy effect is demonstrated when eliminating duplicate content presentation results in improved learning outcomes (Sweller, 2004 cited in Elliot et al., 2009 p. 8).” Instruction must thus be designed in a manner as not to overload the extraneous cognitive load and thus ensure effective learning.

iii. The split-attention effect occurs when learners are called upon to process and integrate multiple and separated sources of information. For instance one can see this when multiple sources of visual information, which are spatially separated, must be brought together to aid comprehension. This integration is necessary because the individual sources of information cannot be understood in isolation. What this means is that when materials are split learners must also split their attention in order to ensure comprehension.

iv. Any instruction that aims at promoting learning should include learning tasks within the limits of the Zone of Proximal Development (ZPD). If the task difficulty were higher than the ZPD, the learner's cognitive capacity would be overwhelmed, because the cognitive load would exceed the learner's working memory capacity. If the task difficulty were lower than the ZPD, the learner would be sub-challenged and a great deal of the available cognitive capacities would remain unused for the learning process. Accordingly, the difficulty of learning tasks has to be adapted to the learner's zone of proximal development by, for example, choosing other learning tasks or defining other task performance conditions.

v. Sweller has in addition to these effects also identified effects on the cognitive load. These include the worked examples effect, the problem completion effect, the guidance fading effect, and the imagination effect among others. The worked examples effect for instance says that using known and resolved examples diminish cognitive load and improves comprehension. In the design of instruction therefore such examples and scenarios should be provided to aid comprehension. In the classroom situation teachers also ought to recognize this fact. The problem completion effect as a follow up to the worked examples effect says that unworked examples should be provided after worked ones to encourage the motivation of students to try out things for themselves. The imagination effect calls for mental stimulation of experts to allow for better learning results. It is important that learning task difficulty is adapted to the Zone of Proximal Development (ZPD). The lower limit of the ZPD is conceptualized as the most difficult task the learner can perform successfully without while the upper limit of the ZPD is defined as the most difficult task the learner can perform with the best possible help. Learning tasks ought to be assigned with the upper and lower limits of the ZPD in mind. The learner need not be overwhelmed by tasks that exceed their working memory because it is above the upper limit of the ZPD or sub-challenged because such tasks are below the lower limit of the ZPD and thus leaves them with unused cognitive capacities. Recent studies (Kalguya, Chandler, & Sweller, 2001; Cooper, Tindall-Ford, & Sweller, 2001 cited in Schnotz & Kurschner, 2007), are helpful in indicating that instructional design takes cognizance of the above and manipulate extraneous and intrinsic load in order to bring them in line with the task requirements and the learners ZPD or level of expertise.

vi. The complexity of the learning material ought to be considered in deciding on tasks that require individual or collaborative learning. Kirschner, Pass, & Kirschner, 2009 (cited in Kirschner, Ayres & Chandler, 2009), have suggested that "when groups work together on complex instructions or problems they have a heightened level of confidence in their ability, as they are aware they can spread working memory load amongst other members of the group" (pp. 6-7). The "group effect" according to these researchers cut across disciplines.

vii. Even though the research on learner control is ongoing, the literature seem to indicate that some learners benefit from learner control more than others (Kopcha & Sullivan, 2007; Katz & Assor, 2007). The lesson for instructional designers especially those developing for e-learning and distance learning environments, is that cognitive overload even for expert learners can be daunting as they might experience difficulties in selecting, sequencing and pacing huge amounts of information.

CONCLUSION

It is clear from the above that the process of instructional design has benefited immensely from research in cognition. As advances continue to be made through research in both learning and cognition one hopes that the benefits to the process of learning and the design of such learning will be further enhanced. The fact that some research have indicated challenges with CLT, especially when measuring learning in complex environments and with novice learners among others, and the presence of confounding variables in real learning situations should not intimidate the benefits of CLT for instructional design and learning enhancement in higher education.

REFERENCES

Angeli, C., & Valanides, C. (2009). Instructional effects on critical thinking: Performance on ill-defined issues. *Learning and Instruction*, 19, 322-334.

Azimi, S., &Fazelian, P. (2013). New trends and approaches in instructional design and technology. *Procedia - Social and Behavioral Sciences,* 82, 525 – 528.

Branch, R. M. (2008). *Instructional design: The ADDIE approach*. New York: Springer.

Chandler, P. &Sweller, J. (1991). Cognitive load theory and the format of instruction. *Cognition and Instruction*, *8*(4), 293-332.

Cooper, G. (1998). Research into cognitive load theory and instructional design at UNSW. Dr. Graham Cooper, School of Education Studies, The University of New South Wales. Downloaded from http://education.arts.unsw.edu.au/C LT_NET_ Aug_97 .HT ML

Cooper, G., Tindall - Ford, S., Chandler, P., &Sweller, J. (2001). Learning by imagining. Learning of *Experimental Psychology: Applied*, 7, 68–82.

De Jong, T. (2010). Cognitive load theory, educational research, and instructional design: Some food for thought. *Instructional Science*, 38, 105-134.

Erland-Burkes, K. M. (2007. Applying cognitive load theory to the design of online learning. Unpublished doctoral dissertation, University of North Texas.

Elliott, S. N., Kurz, A., Beddow, P. & Frey, J. (2009) Cognitive Load Theory: Instruction- based Research with Applications for Designing Tests. Paper Presented at the national Association of School Psychologists' annual convention, Boston, MA.

Gerjets, P., Scheiter, K., & Cierniak, G. (2009). The scientific value of cognitive load theory:

A research agenda based on the structuralist view of theories. Educational Psychology Review, 21, 43–54.

Kalyuga, S., Chandler, P., & Sweller, J. (2001). Learner experience and efficiency of instructional guidance. Educational Psychology, 21, 5–23.

Kalyuga, S. (2007). Enhancing instructional efficiency of interactive e-learning environments: A cognitive load perspective. Educational Psychology Review, 19, 387–399.

Katz, I. & Assor, A. (2007). When Choice motivates and when it does not. Educational Psychology Review, 19, 429-442.

Kirschner, P. A. (2002). Cognitive load theory: Implications of cognitive load theory on the design of learning. Learning and Instruction 12, 1-10.

Kirschner, F., Paas, F., & Kirschner, P. A. (2009). A cognitive load approach to collaborative learning: United brains for complex tasks. Educational Psychology Review, 21, 31-42.

Kirschner, P. A., Ayres, P., & Chandler, P. (2009.). Contemporary cognitive load theory research: The good, the bad and the ugly. Current Research in Cognitive Load.

Theory. 3rd Internal Conference on Cognitive Load Theory in Heerlen, the Netherlands Downloaded from http://dspace.ou.nl/bitstream/1820/2881/1/Contemporary%20Cognitive%20Load%20Theory%20Research%20%20The%20Good,%20the%20Bad%20and%20the%20Ugly.pdf

Kopcha, T. J., & Sullivan, H. (2007). Self-presentation bias in surveys of teachers' educational technology practices. Educational Technology Research and Development, 55, 627–646.

Morrison, G. R., Ross, S. M., & Kemp, J. E. (2004). Designing effective instruction (4 th ed.). Hoboken, NJ: John Wiley and Sons.

Morrison, G. R., Ross, S. M., Kelman, H. K., & Kemp, J. E. (2011). Designing effective instruction (6 th ed.). Hoboken, NJ: John Wiley and Sons.

Mousavi, S.Y., Low, R., & Sweller, J. (1995). Reducing cognitive load by mixing auditory and visual presentation modes. Journal of Educational Psychology, 87(2) 319-334.

Paas, F., van Gog, T., & Sweller, J. (2010). Cognitive load theory: New conceptualizations, specifications, and integrated research perspectives. Educational Psychology Review. 22, 115–121

Paas, F., Renkel, A. & Sweller, J. (2003) Cognitive load theory and instructional design: Recent developments. Educational Psychologist, 38(1), 1-4.

Quiroga, L. M., Crosby, M. E. & Iding, M. K. (2004). Reducing cognitive load. Proceedings of the 37th Hawaii International Conference on System Sciences.

Smith, P. L., & Ragan, T. J. (2005). Instructional design. Hoboken, NJ: John Wiley Sons.

Schnotz, W., & Kurschner, C. (2007). A reconsideration of cognitive load theory. Educational Psychology Review, 19, 469–508.

Sweller, J. (2004). Instructional design consequences of an analogy between evolution by natural selection and human cognitive architecture. Instructional Science, 32, 9–31.

Sweller, J., van Merrienboer, J. G. & Paas, F. (1998). Cognitive architecture and instructional design. Educational Psychology Review 10(3), 8.

Tarmizi, R., & Sweller, J. (1988). Guidance during mathematical problem solving. Journal of Educational Psychology, 80, 424-436.