The seminar paper entitled

Information Processing: Implications for Adult Education Practices

Is approved by Tom Lo Guidice on February 29, 2012

Information Processing: Implications

For Adult Education Practices

A Seminar Paper

Presented to

The Graduate Faculty

University of Wisconsin-Platteville

In Partial Fulfillment of the

Requirement for the Degree

Masters of Science

in

Education

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by

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February 2012

Abstract

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Human cognitive architecture, responsible for learning, is part of a powerful and complex communications network. Learning occurs as information is processed by cognitive structures in a series of steps with critical points and parameters. Research suggests that understanding cognitive structures and how they function can improve instructional design and, in turn, enhance learning. This paper presents a review of research literature to determine the relationship between cognitive architecture, information processing systems and learning. In addition, implications and recommendations for instructional design strategies are presented.

Cognition has been the focus of cognitive research and led to numerous learning theories. Information processing is one learning theory that correlates instructional strategies to each step of the three part memory system; sensory, working, and long-term memory.

Cognitive Load Theory (CLT) is a learning theory focused on working memory and defines information processing in terms of load and capacity limitations. Evidence based instructional design strategies are suggested for each step of the memory process, as well as, for managing cognitive load.

Students pursuing careers in healthcare must acquire vast amounts of information. It is not uncommon for students to feel overwhelmed and experience information overload. Research suggests poor instructional design may interfere, obstruct, and overload the information processing system. When this happens, learning fails. The review of literature will show that designing instruction to work with cognitive architecture has proven implications adult education practices.

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Chapter I Introduction

In health science courses, it is not uncommon for students to feel overwhelmed and experience information overload. Students pursuing careers in healthcare must acquire vast amounts of information, technical clinical skills, and ethical attitudes of the profession. Students must learn complex body system structures and their functions in conditions of health and disease. Moreover, health professionals are required to learn the medical language which has been compared to learning a non-native language. According to research, health science coursework places heavy demands upon cognitive structures responsible for learning (van Merrienboer & Sweller, 2010). The study of how our minds work, how we remember, and ultimately, how we learn is the focus of cognitive research (Connor, 2007). Therefore, an examination of cognitive research and the implications for adult education is warranted.

Human cognitive architecture responsible for learning is part of a powerful and complex communications network. Understanding cognitive structures and how they function can improve the way we teach (Connor, 2007). Although the human brain has been studied for thousands of years, scientist have yet to unravel the all the mysteries of intelligence, personality, preferences, imagination, learning and memory (Huitt, 2003). However, recent advances in cognitive research and brain imaging technology have added significantly to our understanding of how information is processed and learning occurs (Brain facts, 2008). Brain structures communicate through a vast network of neural connections and perform complex functions that control and direct all of life’s vital functions, critical thinking, actions and reactions, emotions and learning (Brain facts, 2008; Longenbaker, 2011). Cognitive brain structures carry out the essential processing of information that leads to learning (Brain facts, 2008).

Cognitive learning theory, which gained popularity in the 1960's, is based upon how the brain processes information. Cognitive psychologists likened the human brain to a computer processor (Martinez, 2010). Cognitive structures, called schema, were shown to provide the mental framework in which information was programmed, formatted, reformatted and saved (Connor, 2007; Martinez, 2010). However, unlike a computer, the human memory system is selective, has processing limitations, and unlimited space for storing information (Connor, 2007; Martinez, 2010). Information processing theory, a model of learning based upon the mental processes of cognition, has yielded numerous instructional design strategies (Huitt, 2003).

Cognitive Load Theory (CLT) is rooted in and expands upon cognitive learning theory and information processing theory. CLT explains learning in terms of the *load* imposed by new information and the limited *capacity* of working memory (van Merrienboer & Sweller, 2010). Managing the relationship between cognitive load and cognitive resource capacity for optimal learning is the goal of CLT (van Merrienboer & Sweller, 2010).

Instructional design strategies based on cognitive learning theory are grounded in authentic research and shown to improve the design, delivery, and retention of instruction (Connor, 2007). According to van Merrienboer and Sweller (2010), CLT design principles are extremely useful for teaching the health sciences.

Statement of the Problem

Learning occurs as information is processed by cognitive structures in a series of steps with critical points and parameters. Information processing models of learning aim to design instruction to work with human cognitive architecture. The problem to be addressed is what are the implications of information processing on adult education practices?

Definition of Terms

1. Sensory memory is the mental spaces that receive sensory information (van Merrienboer & Sweller, 2010).
2. Working memory are mental workspaces that process, assimilate and organize information (van Merrienboer & Sweller, 2010).
3. Long term memory is the mental structures that store information for long periods of time (van Merrienboer & Sweller, 2010).
4. Intrinsic cognitive load refers to the inherent complexity of information to be learned and the corresponding amount of working memory capacity required for processing (van Merrienboer & Sweller, 2010).
5. Extraneous cognitive load refers to information that requires processing in working memory but doesn’t contribute to learning (van Merrienboer & Sweller, 2010).
6. Germane cognitive load refers to working memory capacity used for making sense of information and the actual learning (van Merrienboer & Sweller, 2010).

Delimitations of Research

The references used for the review of literature were collected over a period of 60 days using the resources of the Karmann Library at the University of Wisconsin-Platteville. The several search engines provided by EBSCOHOST were used. Key search terms were "information processing", "working memory", "neuroscience", "cognitive load" and "health science education".

Method of Approach

A brief review of literature on the human cognitive architecture and the history of cognitive learning theory were conducted. A comprehensive literature review on the information processing and cognitive load learning theories were conducted. A review of literature regarding instructional design and cognitive learning theory and anecdotal evidence of adult students in health science courses was conducted. The findings were synthesized, summarized and recommendations made.

Chapter II Review of Literature

Overview of Human Cognitive Architecture

Brain structures of human cognition, also called knowledge structures, are the essential component parts for processing information that account for learning (Ifenthaler, Masduki, & Seel, 2009). As shown in Figure 1, major cognitive structures include the cerebrum, cerebral cortex, thalamus, hypothalamus, hippocampus, cerebellum, and amygdala (Brain facts, 2008; Longenbaker, 2011). The cerebrum is the largest part of the brain and functions to communicate with and coordinate all the activities of the rest of the brain. Higher level thinking processes required for learning and memory is directed by the cerebrum (Brain facts, 2008; Longenbaker, 2011). The cerebral cortex is the deeply convoluted outer covering of the cerebrum and is divided into four sections called lobes. Cortical lobes play key roles in processing sensory information, attention, emotion, thinking, planning, and language (Brain facts, 2008). The medial temporal lobe is richly connected to widespread areas of the cerebral cortex and important for forming, organizing, consolidating, and retrieving information (Brain facts, 2008).

Acting as a relay station, the thalamus receives and directs sensory input from the sensory organs of touch, taste, smell, sight and sound (Brain facts, 2008).

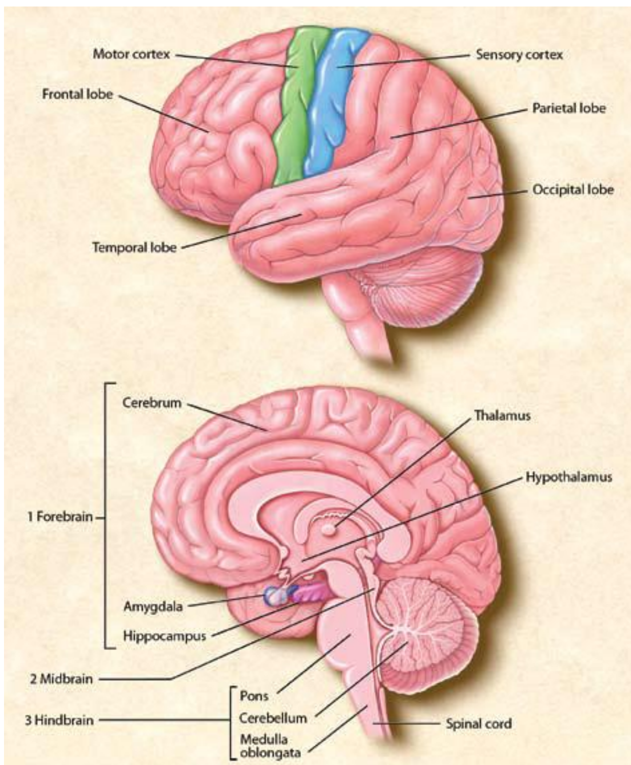

Figure 1. Major cognitive structures. This figure shows two views of the brain and identifies the location of cognitive structures. (Brain facts, 2008)

The hippocampus, a seahorse shaped organ below the thalamus, is vital to the processing of episodic memories: personal experience and events (Brain facts, 2008). The cerebellum assists in the learning of new motor skills, controls movement and coordination (Brain facts, 2008; Longenbaker, 2011). Lastly, the amygdala plays an important role in the emotional aspects of memory by attaching emotional significance to otherwise neutral information and events (Brain facts, 2008). Together, these hidden cognitive structures make up the powerful and complex information processing system that ultimately lead to learning (Brain facts, 2008).

Overview of Cognitive Theory

Cognition simply means knowing. Cognitive theory is the study of cognition and focuses on how one comes to know. Over his lifetime, Jean Piaget, (1896-1980) made significant contributions to the understanding of cognition through research focused on human cognitive structures and functions in acquiring and maintaining knowledge (Huitt, 2003). Other important cognitive theorists are Ausubel, Bruner, Gagne, Miller and Sweller (Conner, 2007; Huitt, 2003).

Within the framework of cognitive theory, a number of theoretical models with implications for education have emerged. Information processing theory is one focused primarily on memory and how information is received, stored and retrieved (Huitt, 2003; Terrell, 2006). “Memory is one of the most important concepts in learning: if things are not remembered, no learning can take place” (Kearsley, 2007).

As shown in Figure 2, memory is formed in a 3-step process as information moves from sensory memory (SM) to working memory (WM), also called short term memory, and on into long term memory (LTM) (Terrell, 2006). Step one involves the initial process of sorting out important information items from the steady stream of messages being sent from sensory organs. Sensory memory holds information briefly, lasting about .25 seconds for visual images and up to 3 seconds for auditory input (Huitt, 2003; Mayer 2010; Terrell, 2006). At this point, it is absolutely critical that the learner attend to the information to-be-learned (Joyce et al., 2008). For, only information items that are attended to are forwarded onto the second step of the process: working memory (Joyce et al., 2008).

Step two involves the process of assimilating and encoding information to fit LTM and lasts slightly longer, from 15 to 30 seconds (Huitt, 2003). At this step, keeping the information active is essential for proper processing (Terrell, 2006). Two key features of WM are limited duration and limited capacity for the number of "new" items it can process at any one time (Huitt, 2003). Miller (1956) first presented the concept of "chunks" as meaningful units of information and that the working memory could manage no more than 5-9 chunks at any one time (Huitt, 2003; Terrell, 2006). More recent research suggests the number may be even less: 3-7 chunks of information (Huitt, 2003). This limitation can create a "bottleneck" in the memory system process and obstruct learning (Huitt, 2003).

Information processed by working memory is then stored in LTM, step three. LTM has unlimited storage capacity and can last a lifetime (Huitt, 2003; Mayer, 2010). Information held in LTM is organized into structures, collectively called schema, that categorize and store information into a meaningful system (Huitt, 2003). Schemas are created as new information is structured into new schema and changeable as new information is assimilated into existing schema, or existing schemas are restructured (Huitt, 2003; Terrell, 2006).

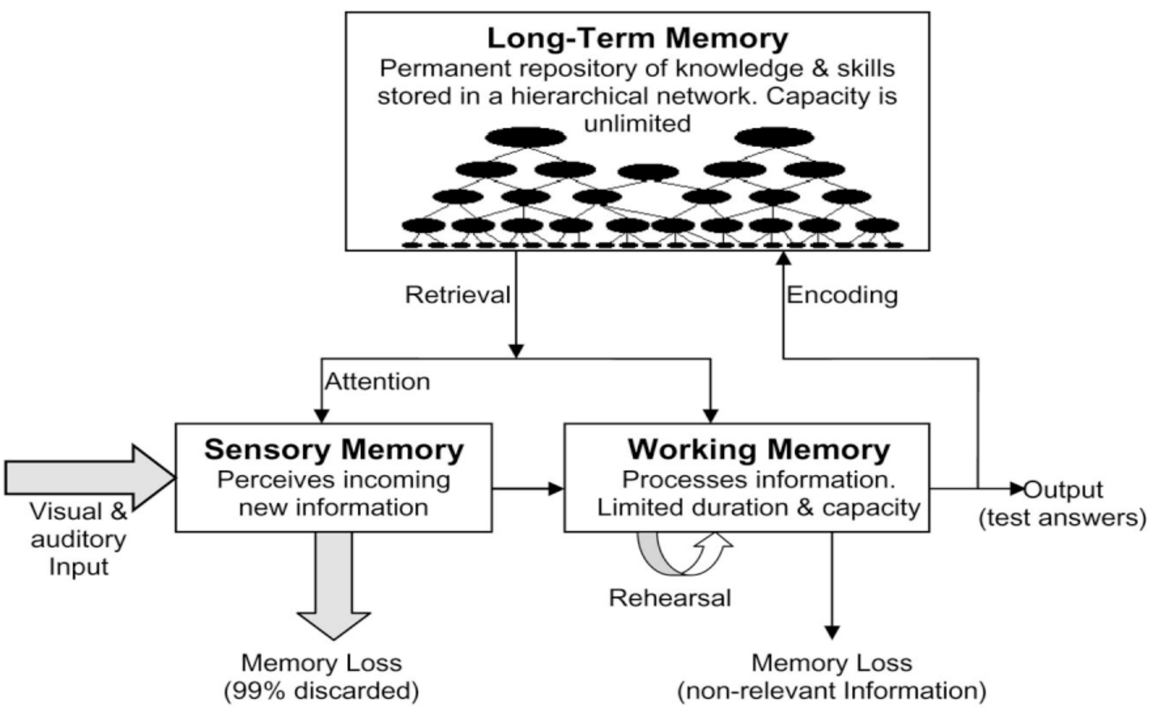

Figure 2. Cognitive architecture. This figure illustrates the three-step process of the human memory system based on information processing theory. (Terrell, 2006)

Cognitive Load Theory

Cognitive load theory (CLT) is rooted in and expands upon cognitive learning theory with an interest in optimizing cognitive processing capacities through understanding the demands learning places on cognitive resources. Cognitive load research aims to provide meaningful measures of working memory capacity and strategies to fully utilize those capacities to improve instruction and learning (Terrell, 2006). CLT has become a leading instructional theory recognized around the world by researchers and educators alike (UNSW, 2011). John Sweller, Emeritus Professor of the School of Education at the University New South Wales (UNSW), Sydney Australia, pioneered the original research in the 1980's and continues to lead the study of this theory. Other principal CLT researchers include Ayres, Jin, Kalyuga, and Low (UNSW, 2011). According to experts in the field, "a major strength of CLT research is that it has been carried out in ways that mirror real world complex learning environments" (Kirschner, Ayers, & Chandler, 2011).

CLT makes the following assumptions about human cognitive architecture. Working memory has limited capacity that can hold no more than five to seven information items at one time and actively process no more than two to four information items at one time (van Merrienboer & Sweller, 2010). Long-term memory has unlimited capacity and stores information in schema, also called knowledge structures (van Merrienboer & Sweller, 2010).

CLT identifies three types of cognitive load that use up cognitive processing resources: *intrinsic load*, also called essential cognitive processing, *extraneous load*, and *germane load,* also called generative cognitive processing (Mayer, 2010; van Merrienboer & Sweller, 2010). Intrinsic load represents essential information and the inherent complexity of the information to-be-learned (Mayer, 2010; van Merrienboer & Sweller, 2010). Extraneous load represents nonessential information that does not contribute to learning and is caused by poor instructional design (Mayer, 2010; van Merrienboer & Sweller, 2010). Germane load represents working memory resources used to organize, assimilate and encode intrinsic load, which leads to learning (Mayer, 2010; van Merrienboer & Sweller, 2010).

Not everyone agrees that there ought to be three types of load. Kalyuga (2011), a colleague of Sweller, suggests a dual model of intrinsic and extraneous load is sufficient. Kalyuga suggests intrinsic and germane load are essentially the same and thus, redundant.

As shown in Figure 3, total cognitive load is the sum of the different types of load and represents the amount of cognitive activity taking place in working memory at any moment in time. If the sum total cognitive load exceeds working memory capacity, then learning fails.

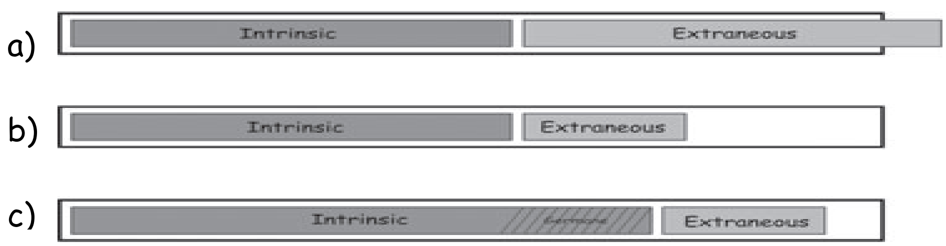

Figure 3. Cognitive Loads. This figure illustrates the additive nature of intrinsic and extraneous load: (a) overload; (b) preventing overload by decreasing extraneous load, and (c) optimizing germane load by increasing intrinsic load. (van Merrienboer and Sweller, 2010)

The goal of CLT is to design instruction that minimize extraneous load, manage intrinsic load and maximize germane load to optimize learning (van Merrienboer and Sweller, 2010).

A major factor contributing to cognitive load is the number of new items that need to be processed (van Merrienboer and Sweller, 2010). New information lacks organization and each item must be handled as a separate unit (van Merrienboer and Sweller, 2010). In contrast, information retrieved from LTM is organized in schema and can be highly detailed and complex. (van Merrienboer and Sweller, 2010). Schemas are treated as one single item in WM which greatly reduces cognitive load (van Merrienboer & Sweller, 2010).

Implications for Adult Education

The goal of cognitive learning theory is to design instruction that works with human cognitive architecture. Understanding cognitive structures and how they function can help guide the design, delivery, and retention of instruction from orientation through final exams. The information processing models of learning provide a framework of mental processes from which instruction is designed to focus attention, keep information active and facilitate the construction and automation of schema. Due to the large amount of information and inherent complexity of health science coursework, information processing models of instruction are highly relevant.

Scientific evidence supports the following instructional design strategies and practices. The first section provides an overview of strategies based on each step of the information processing model. Appendix A, Table 1 summarizes instructional design based on information processing theory. The second section explains best educational practices based on CLT. Appendix B, Table 2 summarizes instructional design based on CLT. (van Merrienboer & Sweller, 2010)

Information Processing Model.

Attend: To-be-learned information must be attended to in order for it to be moved from sensory memory onto working memory. Two key strategies for stimulating attention are to introduce information with an interesting feature and use a known pattern that triggers retrieval of some prior learning. (Huitt, 2003; MacLeod, 2010)

Active: Strategies that keep information active in working memory are important to extend processing time. Rehearsal is one strategy that can extend processing time up to 20 minutes (Joyce, et al.; 2008; Huitt, 2003). During rehearsal, retrieval cues are developed that facilitate and strengthen recall (Joyce, et al., 2008; MacLeod, 2010). Miller's concept of chunking, also called segmenting, has become an important organizational strategy for getting and keeping information in working memory (Huitt, 2003). Chunking breaks apart large lesson plans into smaller more manageable units of information (Mayer, 2010; Huitt, 2003).

Archive: Encoding is the processing and transfer of information from WM to LTM (MacLeod, 2010). Four powerful learning strategies for effective encoding are imagery, elaboration, generation, and production (MacLeod, 2010; Huitt, 2003). Imagery is the ability to store visual images and facilitates recall (MacLeod, 2010). Imagery is also associated with sensory motor skills as one is able to mentally picture themselves performing a skill (Kearsley, 2007). Elaboration expands the learner's knowledge base by connecting new information to the things the learner already knows (van Merrienboer and Sweller, 2010; Huitt, 2003; MacLeod, 2010). Generation effect, also called the testing effect, requires the learner to retrieve information from LTM which improves retention more than rereading or relearning the information (MacLeod, 2010; Huitt, 2003; Kirschner, et al., 2011). Furthermore, being unable to retrieve information identifies areas needing more study and therefore is also beneficial to learning (Kirschner, et al., 2011).

Lastly, the production effect, suggests words read out load enhances remembering by giving the words a distinctive quality (MacLeod, 2010). "The basic idea of distinctiveness as an explanatory mechanism is that information which is made to stand out from other information at the time of encoding will show enhanced memory." (MacLeod, 2010, p. 233) According to MacLeod, 2010, mouthing the word or even imagining saying the word out loud is equally effective for improved retention.

Instructional design principles based on CLT have been grouped into three sections based on these three goals: (a) reduce extraneous load, (b) manage intrinsic load, and (c) optimize germane load.

Reduce extraneous load.

The *goal-free principle* is when conventional problem solving tasks with specific end goals are replaced with goal-free tasks with non-specific end goals (van Merrienboer & Sweller, 2010). Essentially, the learner takes what information is given and applies it where ever possible. Goal-free tasks prompt a forward thinking cognitive process: a more advanced method of problem solving that reduces cognitive load and facilitates learning (van Merrienboer & Sweller, 2010). *The worked example principle* is when problems with worked out solutions are given for the learner to study the problem solving process from beginning to end (van Merrienboer & Sweller, 2010). Worked examples provide a framework for solving the problem and guide the learner to the solution. This principle eliminates the guesswork and reduces cognitive load caused by poor problem solving skills of new learners (Paas, Gog, & Sweller, 2010). In a recent study, students were given worked example problems and to-be-solved problems, both with varying ratios of steps (Kirschner, et al., 2011). Worked examples reduced extraneous load whereas to-be-solved problems increased extraneous load no matter the ratio of steps (Kirschner, et al., 2011). Closely related to the worked example principle is the *completion principle*. Extraneous load is reduced by having the learner finish finding the solution to partially worked out problems (van Merrienboer & Sweller, 2010).

The s*plit attention principle* is when learning materials from different resources are combined into one source and/or presented at the same time (van Merrienboer & Sweller, 2010). This principle eliminates the mental energy it takes to integrate information from different places or that would have been presented at different times (van Merrienboer & Sweller, 2010). In the same way, the r*edundancy principle* is when needless repetition of information is eliminated (van Merrienboer & Sweller, 2010).

The modality principle is when a spoken rather than written explanation is given with a visual source of information (Mayer, 2010). This combination makes use of the separate channels for processing auditory and visual information which reduces the load on working memory (Mayer, 2010).

Manage intrinsic load.

The *simple-to-complex* strategy is when a series of conventional tasks is replaced with tasks that begin with singular elements and gradually adding elements until the full complexity of the task is learned (van Merrienboer & Sweller, 2010). The *low- to high-fidelity* strategy is when learning a task increasingly becomes more and more like that of real world practice (van Merrienboer & Sweller, 2010). The learner progresses from performed in a low-fidelity environment such as a simulation, and then progress to higher-fidelity environments that resemble real world practice (van Merrienboer & Sweller, 2010).

Optimize Germane Load.

The *variability principle* “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.” (van Merrienboer & Sweller, 2010) This principle requires the learner to think carefully about some quality or characteristic of a problem that is capable of changing. This thinking process encourages schema construction as information is reorganized and solutions formulated. Similarly, the *contextual interference principle* changes the order of tasks so that knowledge and skill sets required to complete the task are random rather than being grouped together (van Merrienboer & Sweller, 2010).

The *self-explanation principle* is when the learner is asked to explain what they have learned (van Merrienboer & Sweller, 2010). This principle requires the learner to assimilate prior learning with new learning and promotes schema construction.

Chapter III Conclusions and Recommendations

From the review of research literature, substantial evidence is found in support of instruction designed to work with human cognitive architecture. Structures of cognition are connected through a vast and changeable network of neurons that transmit process and store the volumes of information learned over a lifetime. Cognitive learning theory has a solid base of empirical studies and ongoing contemporary research which have made it a leading instructional design theory.

Information processing theory provides a mental model of the pathways and processes that lead to learning. Learning occurs as information is attended to in sensory memory, assimilated and understood in working memory and stored in the appropriate location and format in long term memory schema. Accordingly, strategies that focus attention and keep information active in working memory should be incorporated into instruction. Recall of prior learning and rehearsal are two such strategies. In addition, research suggests that imagery, elaboration, generation, and production are four powerful strategies for encoding information into LTM.

Cognitive load theory offers practical design strategies aimed at effective information management in order to prevent cognitive overload and facilitate optimum load. The limitations of working memory require instructors to identify and reduce extraneous elements that do not contribute to learning. Using worked examples and integrating sources of information are two strategies that reduce extraneous load. Material that is inherently complex can also surpass WM capacity and must be managed to prevent intrinsic overload. Breaking apart the material into smaller chunks, and building from simple to complex elements are two strategies to manage intrinsic load. CLT also suggests strategies that increase germane load into order to utilize the full capacity of WM which will lead to optimal learning. The variability principle and contextual interference principle require information learned to be applied in new ways which increases germane load and promotes schema construction and connections. Similarly, the self-explanation principle requires the learner to construct and communicate the meaning of newly acquired information. Although there is debate over the naming of two or three types of cognitive load, the implications for adult education practices remain.

In conclusion, information processing has significant implications for adult education. Future cognitive research will likely increase our understanding of cognition. Translating the research into instructional design strategies will continue to improve adult education, including health science coursework.

References

Conner, M. L. (2007). A Primer on educational psychology. Retrieved from http://agelesslearner.com/intros/edpsych.html

Huitt, W. (2003). The information processing approach to cognition. Retrieved from http//www.edpsychinteractive.org/topics/cogsys/infoproc.html

Iftenthaler, D., Masduki, I., & Seel, N. M. (2011). The mystery of cognitive structure and how we can detect it: Tracking the development of cognitive structures over time. *Instructional Science, 39* (1), 41-61. doi: 10.1007/s11251-009-9097-6

Joyce, B., Weil, M., & Calhoun, E. (2008). *Models of teaching.* (8th ed.). Pearson Education, Inc., Boston.

Kalyuga, S. (2011). Cognitive load theory: How many types of load does it really need? *Education Psychology Review, 23*, 1-19. doi: 10.1007/s10648-010-9150-7

Kearsley, G. (2007). Memory. Retrieved from http://home.sprynet.com/~gkearsley/tip/memory.html

Kearsley, G. (2007). Imagery. Retrieved from http://home.sprynet.com/~gkearsley/tip/imagery.html

Kirschner, P. A., Ayers, P., & Chandler, P. (2011). Contemporary cognitive load theory research: The good, the bad and the ugly. *Computers in Human Behavior,* 27, 99-105. doi:10.1016/j.chb.2010.03.025

Longenbaker, S. N. (2011). The nervous system. *Mader's understanding human anatomy and physiology*. (7th ed.). (pp. 155-179). New York, McGraw-Hill.

MacLeod, C. M. (2010). When learning met memory. *Canadian Journal of Experimental Psychology, 64* (4), 227-240. doi: 10.1037/a0021699

Martinez, M. E. (2010). Human memory: The basics. *Phi Delta Kappan, 91* (8), 62-65. Retrieved from http://issuu.com/shanedee11/docs/1_-_human_memory_-_the_basics

Mayer, R. E. (2010). Applying the science of learning to medical education. *Medical Education, 44*, 543–549[a]. doi:10.1111/j.1365-2923.2010.03264.x

Paas, F., Van Gog, T., Sweller, J. (2010). Cognitive load theory: new conceptualizations, specifications, and integrated research perspectives. *Educ Psychol Rev., 22*:115–121. doi: 10.1007/s10648-010-9133-8

Society of Neuroscience. (2008). *Brain facts: A primer on the brain and nervous system*. [PDF]. Retrieved from http://www.sfn.org/brainfacts

Terrill, M., (2006). Anatomy of learning: Instructional design principles for the anatomical sciences. The anatomical record (Part B: New Anat.) 289B: 252-260. Retrieved from http://meds.queensu.ca/ohse/assets/anatomy_instru_design_2006.pdf

UNSW: The University of New South Wales at Sydney Australia. (2011). Retrieved from http://education.arts.unsw.edu.au/staff/john-sweller-726.html#Publications https://research.unsw.edu.au/people/emeritus-professor-john-sweller http://education.arts.unsw.edu.au/research-education/cognitive-load-theory/

van Merrienboer, J. J. G., & Sweller, J. (2010). Cognitive load theory in health professional education: Design principles and strategies. *Medical Education*, *44*, 85-93. doi:10/1111/j.1365-2923.2009.03498.x

Appendices

Appendix A

Using the Information Processing Approach in the Classroom

Principle	Example
1. Gain the students' attention.	• Use cues to signal when you are ready to begin. • Move around the room and use voice inflections.
2. Bring to mind relevant prior learning.	• Review previous day's lesson. • Have discussion about previously covered content.
3. Point out important information	• Provide handouts. • Write on the board or use transparencies.
4. Present information in an organized manner.	• Show a logical sequence to concepts and skills. • Go from simple to complex presenting new material.
5. Show how to categorize (chunk) related information.	• Present information in categories. • Teach inductive reasoning.
6. Provide opportunities for students to elaborate on new information.	• Connect new information to something already known. • Look for similarity and differences among concepts.
7. Show how to use coding when memorizing lists.	• Make up silly sentence with first letter of each word. • Use mental imagery techniques such as keyword method.
8. Provide for repetition of learning.	• State important principles several times in different ways during the presentation of information (STM) • Have items on each day's lesson from previous lesson (LTM)
9. Provide opportunities for overlearning of fundamentals.	• Use daily drills for arithmetic facts. • Play form of trivial pursuit with content related to class.

Table 1. Information processing. This table provides principles and practical examples of the information processing theory in education. (Huitt, 2003)

Appendix B

Design principles and strategies recommended by cognitive load theory

Design Guideline	Description	Applied to Health Education
Decreasing extraneous load		
Goal-free principle	Replace conventional tasks with goal-free tasks that provide learners with a non-specific goal.	Ask students to 'Please come up with as many illnesses as possible that could be related to the observed symptoms', rather than asking 'Which illness is indicated by the symptoms?"
Worked example principle	Replace conventional tasks with worked examples that provide full solution learners must carefully study.	Let students criticize a ready-made treatment plan, rather than having them independently generate such a plan.
Completion principle	Replace conventional tasks with completion tasks that provide a partial solution learners must finish.	Let medical interns closely observe a surgical operation and only perform part of it, rather than performing the whole operation.
Split attention principle	Replace multiple sources of information, distributed in space (spatial) or time (temporal), with one integrated source of information.	Provide students with instructions for operating a piece of medical equipment just in time, precisely when they need it, rather than providing information beforehand.
Modality principle	Replace a written explanatory text and another source of visual information (unimodal) with a spoken explanatory text and the visual source of information (multimodal).	Give students spoken explanations when they study a computer animation of the working of the digestive tract, rather than giving them written explanations on screen.
Redundancy principle	Replace multiple sources of information that are self-contained (i.e. they can be understood on their own) with one source of information.	When providing learners with a diagram of the flow of blood in the heart, lungs and body, do not include a verbal description of flow.

Managing intrinsic load		
Simple-to-complex strategy	Replace a series of conventional tasks with tasks that first present only isolated elements (low element interactivity) and gradually work up to the tasks in their full complexity.	Give students tasks that require them to apply basic physical principles of hydrodynamics, such as pressure–volume and pressure–flow relationships, before giving them tasks that require them to apply a full model of how the blood flows through the circulatory system.
Low- to high-fidelity strategy	Replace a series of conventional tasks with tasks that are first performed in a low-fidelity environment (decreased element interactivity), and then in increasingly higher-fidelity environments.	When teaching students medical diagnosis, start with textual case descriptions, continue with computer-simulated patients or patients played by peers, and end with real patients in an internship in hospital.
Optimizing Germane Load		
Variability principle	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.	When describing a particular clinical symptom, illustrate it using patients of different sex, age, physique, medical history etc.
Contextual interference principle	Replace a series of task variants with low contextual interference with a series with high contextual interference.	If students practice different variants of a particular surgical task, order these variants in a random rather than a blocked order.
Self-explanation principle	Replace separate worked examples or completion tasks with enriched ones containing prompts, asking learners to self-explain the given information.	For students learning to diagnose malfunctions in the human cardiovascular system, present an animation of how the heart works and provide prompts that ask them to self-explain the underlying mechanisms.

Table 2. Instructional design principles and strategies. This table provides principles and examples of cognitive load theory in health science education. (van Merrienboer and Sweller, 2010)