A Cognitive Load Theory-Based Framework for Designing an E-Learning Environment

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ABSTRACT

Learning has foundation in learning theories. The organisation of the learning contents to students and the linking of the related or similar contents in the same field of domain knowledge in an e-learning environment should be given a great consideration. From the literature, there are lots of factors that relate to cognitive learning theories that have been incorporated into the development of e-learning systems. Factors such as students’ learning styles models and motivational models have been used in e-learning environment as instruments that lead students in enhancing their learning performance. Hence, this paper presents a framework of an e-learning environment that takes into consideration the significance of cognitive load theory to instructional procedure or design.

Keywords: E-learning environment, cognitive load, learning theories, cognitive architecture

2. OVERVIEW OF COGNITIVE LOAD THEORY

Wong et al [8] described cognitive load theory as a framework of educational design principles based on the attributes and relations between the structures of human cognitive memory model especially the working memory and long-term memory.
The theory has the notion that human cognitive architecture is a natural information processing system, similar to other systems such as evolution by natural selection. According to Wong et al [8] stressed that the theory can be identified by the following principles:

i. Long-term memory and the information store principle: Human cognitive architecture or systems requires a large information store that can be used to direct appropriate activity. The structure that provides this functionality is human long-term memory.

ii. Schema theory and the borrowing and reorganizing principle: The principle assumes learning is through borrowing information from the long-term of others. The borrowed information and the already stored information in the long-term memory are integrated together in such manner it is the new and reorganized information that is stored in the long-term memory rather than the exact copy of the information that was presented from other’s long-term memory. In nutshell, information is stored as schemas rather than as copies. Each schema stored is different from the schema held in the long term of the person from whom it was borrowed, because it is a combination of the borrowed information combined with the information already held in long-term memory.

iii. Problem solving and the randomness as genesis principle: Through learning, knowledge stored in long-term memory is acquired via the borrowing and organizing principle. Knowledge is actually created through problem solving. When solving familiar problems, it requires human cognitive architecture to retrieve schematic information from long-term memory. That is, recognising a problem to a particular class of problems that require a particular solution. Mostly, this cannot generate new knowledge. Dealing with unfamiliar problems has the tendency to discover a new procedure or concept when solving the problems and this generates new knowledge. With unfamiliar problems and the lack of information held in long-term memory, it is expected to randomly choose a procedure and attempt to test that procedure for effectiveness.

iv. Working memory and the narrow limits of change principle: Working memory acts as a medium between the external environment and the long-term memory. The peculiar feature of working memory is its limitation in processing capacity and temporal when dealing with a novel information from the external environment using a random generate and test procedure. The narrow limits of change principle is important to instruction and central to cognitive load. Instructional procedures have to take into consideration the capacity and temporary limits of working memory because recommended procedures leads to increase in working memory load causes inability of students to learn.

v. Long-term working memory and the environmental organizing and linking principle: The operation of working memory differs when organizing novel information from the environment to when using environmental information to organize the information store. Working memory has its limitation in processing capacity when dealing with novel information from the external environment but with long term working memory, it has the capacity to handle previously learned information held in long-term memory. This automatically reduces the burden on working memory and decreases the cognitive load.

Alasraj et al [4] stressed that theorists of cognitive load have developed three distinct types that can affect learner during learning process such as intrinsic, extraneous and germane load. These types are to be considered by the instructor in deciding the most suitable instructional techniques for the learner in order to increase learning outcomes. These are discussed as follows:

i. Intrinsic Cognitive Load (ICL): Cognitive load theory describes that information complexity of learning materials is determined by the level at which the elements interact. The load on short-term memory during learning process depends on the number of elements that has to be processed simultaneously which is the function of the level of interactivity between the elements. The ICL varies on the degree of interactions between elements in the learning material. Learning materials that have single learning elements with the need to learn in isolation have a reflection of low level of element interactivity. With these materials, the short-term memory is low and the intrinsic cognitive load memory is low. When compare with complex materials that have higher degree of elements interactivity cannot be learned in isolation by the learners. It is expected that learners need to learn individual elements and understand the relationship between the individual elements.

ii. Extraneous Cognitive load (ECL): This is the resultant effect of poorly developed instructional materials. The way to reduce the effect of ECL is ruled by the instructional process through which the instructor is given the ability to vary the e-learning tool developed. Short term memory should not be flooded or exposed with an unnecessary ECL when the learner is in the process of constructing and acquiring schemas.

iii. Germane Cognitive load: This is the process of constructing and storing schemas in long-term memory.
The cognitive load effect is demonstrated when the theory is used fundamentally to propose the ways of altering the number of interacting elements which result in new instructional procedure and with enhanced assessment outcomes rather than traditional procedure.

The cognitive load effect generally depends on the elements interactivity of materials and how learners relate with this to achieve study and overall learning outcome. Sweller [3] described various load effects on cognitive that theorists developed in the face of instructional procedures which are depicted in Table 1.

<table>
<thead>
<tr>
<th>Effect</th>
<th>Description</th>
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<tr>
<td>Variability</td>
<td>Under low intrinsic cognitive load, increased variability increases intrinsic load resulting in increased learning if working memory resources are available</td>
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<td>Isolated elements</td>
<td>Under high intrinsic cognitive load, presenting interacting elements as though they are isolated can decrease intrinsic load</td>
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<td>Goal-free</td>
<td>Eliminating a problem goal eliminates the use of means-ends analysis reducing extraneous cognitive load</td>
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<td>Worked example</td>
<td>Demonstrating a problem solution reduces the extraneous cognitive load associated with problem solving</td>
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<td>Split-attention</td>
<td>If mental integration is required, extraneous cognitive load may be reduced by physically integrating disparate sources of information</td>
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<td>Modality</td>
<td>Mental integration can be facilitated by presenting material using audiovisual rather than a visual only format</td>
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<tr>
<td>Redundancy</td>
<td>Demonstrating a problem solution reduces the extraneous cognitive load associated with problem solving</td>
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<tr>
<td>Element interactivity</td>
<td>if intrinsic cognitive load is low, a high extraneous cognitive load may not exceed working memory capacity, reducing extraneous cognitive load effects</td>
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<td>Expertise reversal</td>
<td>Information that is essential for novices may be redundant for experts reversing the relative effectiveness of instructional designs</td>
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<td>Problem completion</td>
<td>Similar to the worked example effect based on partial worked examples and can be used during guidance fading</td>
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<tr>
<td>Guidance fading</td>
<td>Due to expertise reversal, as expertise increases, the guidance provided by worked examples should be decreased and eventually eliminated</td>
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<tr>
<td>Imagination</td>
<td>With sufficient expertise, imagining procedures or concepts can be more effective than studying</td>
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<td>Transient information</td>
<td>The use of technology can transform permanent into transient information increasing extraneous cognitive load.</td>
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For the effective deployment of this theory connecting with technology, instructional designers or developers must place great consideration in the instructional procedures and strategy that promote or lead to successful learning performance. Cognitive load theory provides a platform where instructional designers can control the conditions of learning within an environment. E-Learning can achieve greater success by implementing the design to reduce cognitive load effect, so that learners will be able to learn within the context of their understanding without putting too much load on the memory.

3. RELATED WORKS

Sawicka [2] developed a simulation model of cognitive learning theory where certain features of instruction and the cognitive capabilities of learners are expresses formally and how the resultant model can assist in gaining insights into the learning dynamics that arise from these relationship and providing a new assistance for research teaching and practice in the field of instructional design.

Park et al [1] developed a theoretical framework using cognitive load theory to ascertain several studies with the notion that adding seductive details to instructional materials has detrimental effect. A 2 x 2 experimental design was set up in which a group of 100 high students was selected to learn biology with a multimedia environment that manipulated the presence of seductive details with or without and the modality of the verbal information with high load on screen text versus low load narration.
The research findings demonstrated that students learning performance was significantly higher when seductive details were presented under low load condition than the other conditions. The results suggested that seductive details may foster learning under a low load condition. Adding extraneous load in the form of seductive details fostered learning under the narration condition but not under the on-screen text conditions.

Wong et al [8] carried out an experimental study to explore the effects of transience due to the use of animation-based instructions and spoken information under audio-visual conditions in a cognitive load theory framework. The study was hypothesised in the form that the transient information presented in short sections; animations would be superior to static graphics due to innate ability to learn by observing. The transient information in long sections, animations should lose their superiority over static graphics due to working memory overload associated with large amounts of transient information. In the same way, the modality effect under which audio-visual information is superior to visual information should be obtained using short segments but disappear or reverse sing longer segments as a result of the working memory consequences of long, transient and auditory information. The results obtained supported the hypotheses.

Kluge et al [7] presented combined principles of cognitive load theory and diagnostic error analysis for designing job aids to determine the effects on motivation and diagnostic performance in a process control task. The researchers set up research questions which carried two studies on the design of a procedural aid and the impact of an additional decision aid for process control. Study one is a procedural aid that avoids imposing unnecessary extraneous cognitive load on novices when controlling technical system. Study two is the effect of a decision aid for use before the procedural aid was investigated which was based on the analysis of diagnostic errors committed in study one. The research findings in study one showed that procedural aid is positively affected germane load, attention, satisfaction, motivation, knowledge acquisition and diagnostic speed for novel faults. While in study two showed that novices are able to diagnose both novel faults and practiced faults; and to support novices in dealing with technical faults in process control.

Beserra et al [5] presented a survey methodology in measuring cognitive load in practicing arithmetic using educational video games on a shared displayed. The research study is on the effect of the position on the screen of displayed information and the amount of information received by each student that shared the workspace with respect to the acquired knowledge on the subject matter. The findings from the research study using experimental setup showed that students that worked with more objects and more neighbours improved significantly less in their learning outcome.

4. FRAMEWORK OF E-LEARNING ENVIRONMENT WITH’ COGNITIVE LOAD THEORY

The emphasis on instructional design principles in an e-learning environment is to foster learning and encourage high level of information processing within a given learning materials that attract meaningful elements interactivity without loss of memory information (that relates to cognitive overload) and translates to high level of skill or knowledge acquisition. The Figure 1 depicts the framework of e-learning system based on cognitive load theory to stimulate high performance of learning outcome. The learning environment establishes organised learning materials that assist students in reaching minimum level of difficulty and complexity of the materials and tasks when engaged in the learning process. It incorporates the restructuring and simplification of the materials according to students’ learning abilities or skills. It provides a step-by-step procedure and guidelines to worked examples to assist students in solving similar problems within the context supported with hints, misconceptions, correct and wrong answers.

Through this, students’ level of understanding of the concepts might greatly be tracked and provide feedback to students on specific areas of their weakness and strengths during the course of engaging in the learning process. To reduce cognitive load, extraneous factors such as split-attention and redundancy are completely avoided by the way in which the learning material is organised. An autonomy-supportive teaching method is invoke to increase intrinsic motivation in order to increase germane cognitive load which in turn will increase learning success by providing supportive information to students instead of ready-made answers during students’ demand for answers to some questions. The successful students’ learning outcome is when students can bring up an appreciative knowledge and skill from relevant materials made available to them during learning process and with different teaching techniques deplore into such learning environment.
5. CONTRIBUTION TO KNOWLEDGE
The framework is a platform to assist instructional designers and educational technologists in designing e-learning systems that focus on reducing complexity of learning materials with respect to “elements interactivity” to avoid cognitive overload on the part of students. This would afford students to create effective learning experience and achieve optimal learning outcome.

6. CONCLUSION
The use of technology in educational setting has added a unique creativity to the learning environment. Connecting students’ understanding on cognitive learning theories and processes with technology would play a vital role in e-learning environment. Building instructional designs that can effectively reduce unnecessary cognitive burden on working memory would create enabling environment for students to learn and increase their participation in the learning process that leads to successful learning outcome.

The followings are recommended for post-primary and tertiary schools for quality education delivery in developing countries such as Nigeria:

(i) This framework should be deployed in schools across various levels for effective teaching and learning methods;

(ii) Teachers and lecturers must be well informed about the general knowledge of the underlined principles of the concept (cognitive load theory) for wider recognition and acceptance of the framework;

(iii) Schools should provide adequate and well enabling technological infrastructure for effective deployment

(iv) Instructors and students should be equipped and trained on the usage of e-learning devices and resources for knowledge acquisition and skills.
REFERENCES


Authors’ Profiles

Oluwatoyin C. Agbonifo obtained her B.Sc. degree in Computer Science from the University of Ibadan, Ibadan, Nigeria in 1995, and an M.Tech. and a Ph.D in Computer Science from the Federal University of Technology, Akure, Nigeria in 2005 and 2012 respectively. She has been a lecturer in the Department of Computer Science Department, Federal University of Technology, Akure since 2006. She has authored/co-authored a number of articles at both local and international refereed journals and conference proceedings. She is a regular reviewer in local as well as international scientific/academic journals. Dr.(Mrs.) Agbonifo is a member of the NCS, CPN, IEEE, AACE and OWSD. Her research interest areas include: Personalised and Adaptive E-learning Systems, Digital Game-Based Learning Systems, Web-enabled Applications, Software Engineering and Artificial Intelligence.

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