Prediction of Overall Cognitive Load and Cognitive Efficiency in the Conceptual and Procedural Tasks

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Abstract: The purpose of this study was to investigate the role of self-evaluation, which was based on subjective survey. The importance of cognitive efficiency has been increased. It can be defined as qualitative changes of knowledge gain and mental effort invested to gain. However, there are two different definitions of cognitive efficiency measures: 1) deviation and 2) likelihood models. This study has two goals. First, it was to see the relationship of the self-evaluation with the cognitive load factors. Second, it was to examine that the self-evaluation can be implemented as an alternative indicator of two cognitive efficiency measures. Three hundred thirty-four college students participated to the study. Five factors of cognitive load were measured, and two cognitive efficiency measures were calculated: 1) deviation and 2) likelihood models. The learning content was divided into conceptual and procedural tasks with long and short line length of layout. Pre-test scores were measured for conceptual and procedural contents as a covariate variable. The result indicated that the self-evaluation can be used to predict the overall cognitive load. It had positive correlations with mental efforts and usability for both tasks. However, it had negative correlations with task demand and perceived difficulties for both tasks as well. The results revealed that the self-evaluation showed significant relationships with the cognitive load factors. Regarding the analysis of relationship with cognitive efficiency, the self-evaluation showed significant negative correlations with deviation model based cognitive efficiency for conceptual and procedural tasks. However, interestingly, the self-evaluation showed a significant positive correlation with likelihood cognitive efficiency for procedural task.

Keywords: *Cognitive Load Theory, Self-evaluation, Cognitive Efficiency,*

INTRODUCTION

Cognitive load theory has been receiving increasing attention as one of the most influential multimedia design theories. Cognitive load is mental load imposing learner's cognitive process of working memory to learn new content or perform tasks (Paas, Renkl, & Sweller, 2003). The amount of cognitive load can be spontaneously changed while a learner is processing mental work for learning and performance. If the amount of cognitive load exceeds the capacity of working memory, learner's performance will be slow or hindered due to the lack of free capacity in working memory.

There are three assumptions of cognitive load theory. First, human cognition is based on dual channels to process information. Visual and auditory information formats can be processed simultaneously via the separated information processing channels. Because leaners can process with the separated dual channels it is fine to process two different types of information. Second, working memory capacity is limited. The main function of working memory is to integrate new information and prior knowledge from the long-term memory. However, human can process only limited numbers of information. Because of this limited capacity the amount of learning content should be managed to avoid from being cognitive overload (Clark & Mayer, 2011). Third, element interactivity is a major factor to cause mental load. Element interactivity can be defined as the number of elements that must be simultaneously processed in working memory on learning task (Moreno, 2010). The amounts of element interactivities can be determined with task difficulties and the levels of prior knowledge. If the task is complicated and difficult, the element interactivities increase and cause higher loads in learning and performing tasks. It could be easily overloaded. It is important to manage the element interactivity at appropriate levels to avoid from cognitive overloaded. However, managing the element interactivity is not easy because the mental load resulting from element interactivity varies within learner's proper knowledge and tasks.

Cognitive load theory defines three types of cognitive load depending upon the nature of mental load either necessary or unnecessary for learning: 1) intrinsic, 2) germane, and 3) extraneous cognitive load (Clark, Nguyen, & Sweller, 2006; Paas, Tuovinen, Tabbers, & Van Gervin, 2003). First, intrinsic load is the mental load imposed by the nature of given tasks or learning contents. The learning task is an instructional goal to be learned. If a complex and complicated task is given as an instructional goal, the intrinsic load should be increased. However, even if the same learning task is given to the learners, their intrinsic cognitive load could vary because of their prior knowledge. It is easier for a well experience learner to decompose the given learning task into manageable size processed in working memory. However, a novice learner may perceive the same task as a very difficult one to handle because his prior knowledge is not enough to handle the task.

Second, germane cognitive load is positive mental work to facilitate learning by integrating new knowledge with prior knowledge. It is good for learners to accomplish instructional goals of learning. Thus, it is a good sign to increasing germane cognitive load to facilitate more learning. Germane load needs to be considered as relevant load for learning.

Third, extraneous load is unnecessary work load imposed by poorly designed instruction. It makes learners do irrelevant cognitive process to accomplish instructional goal. Because of the extraneous load caused by unrelated to the instructional goal, it wastes cognitive capacities of working memory. Well-designed instruction will reduce extraneous cognitive load and facilitate learning in efficient ways.

Overall cognitive load is summation of three types of cognitive load. It forms accumulated work load by the subclasses on a given moment of learning. While a learner is processing tasks, the three types of cognitive loads are spontaneously changing interacting with each other throughout the whole task. The amount of cognitive loads fluctuate while one rises and the other decreases within the capacity of given cognitive resources.

Three cognitive loads can be theoretically exclusive well but hard to separate how they are contributing to the total amount of cognitive load in practical sense. The assumption of the classification of cognitive load is based on uni-dimensional perspective. However, measuring cognitive load is not easy task to do because respondents cannot differentiate the types of cognitive load merely responding to questionnaire. Although the three types of cognitive load are theoretically sound, it contributes mutually in a manner of multi-dimensional perspective. For this reason it is hard to find a set of instrument corresponding exactly to the different types of cognitive loads. The overall cognitive loads regardless of types of load are showing the level of cognitive process being manipulated in working memory. Efficient allocation of cognitive capacities for learning is critical for better learning. It is very important to make predictions of cognitive load to gauge the cognitive capacity for learning. The purpose of this study is to propose an alternate self-report scale in measuring cognitive load and efficiency indices.

Cognitive efficiency

Cognitive efficiency is a variable of indicating how a student learns efficiently. High cognitive load seems easily to cause hindrance of learning while low cognitive load may have more capacities of working memory to process more learning contents. Likewise the concept of cognitive load, cognitive efficiency is similar. Cognitive efficiency can be generally defined as qualitative changes of knowledge acquisition in relation to the mental work or time invested on learning (Hoffman, 2012). Furthermore, the usefulness of cognitive efficiency has been in the center of increased attention. The cognitive efficiency is assumed that it could be very useful to show several properties simultaneously. For instance, it describes how much a learner exploits his mental effort to earn the same learning outcomes. However, in spite of the increased attention of usefulness implying cognitive efficiency, it has been criticized that lack of conceptual clarity of the concept.

There are two representative methods to measure cognitive efficiencies differing from conceptual definitions. First, a deviation model is one of the most popular measuring methods of cognitive efficiency. Many literatures from the perspective of cognitive load theory more preferably refer this model. The definition of cognitive efficiency, deviation model, describes that cognitive efficiency can be measured by the difference between standardized performance and mental effort (Paas & van Merriënboer, 1993). Second method is the likelihood model that compares the ratio between performance and time or effort (Hoffman & Schraw, 2010). By comparing two elements it can measure how a student efficiently performs based on the cost factor. Measuring cognitive efficiency is important because it can provide contextual information of learning conditions. When cognitive efficiency is being measured, two elements should be calculated regardless of the different concepts. Thus, it can include additional information about the students are in.

However, because of the different definitions of cognitive efficiency, there are some practical issues to apply. The definitions vary depending upon what elements are included to calculate the cognitive efficiency. Moreover, the definitions of cognitive efficiency might have different implications. For instance, the deviation model is appropriate to measure individual cognitive efficiency within the same implementation conditions. However, it does not provide comparable information among different types of task if the learning conditions changed. On the other hand, the likelihood model can provide overall estimation of cognitive efficiency without considering the same treatment condition.

Based on the problems of various definitions and implementation conditions for the cognitive efficiency, it is worth to find alternative indicators of cognitive efficiency. This study focuses on investigating the possibility of using self-evaluation as an alternative measure of cognitive efficiency and, furthermore, overall cognitive load. The self-evaluation as a part of cognitive load factors has been proposed in the previous study. It was to identify key construct of cognitive load measures (Ryu & Kim, 2010). Five factors are 1) Task demand, 2) Mental effort, 3) Task difficulties, 4) Self-evaluation, and 5) Usability of learning material.

The purpose of this study was to investigate the relationship of self-evaluation with cognitive load factors and cognitive efficiency measures. The relationship between self-evaluation and cognitive load factors will indicate how the self-evaluation can represent to the overall cognitive load measure. Furthermore, the relationship between the self-evaluation and two cognitive efficiency measures will be investigated to see the self-evaluation can be used as an alternative measure of cognitive efficiency.

METHOD

Participants

Three hundred thirty-three college students were participated to this research. The gender ratio was 194 (58.1%) and 140 (41.9%) for female and male respectively. The grade levels were 38 freshmen (11.4%), 114 junior (34.1%), 117 sophomores (35.0%), and 65 senior (19.5%). The students voluntarily participated as a part of course activities.

Materials

The learning content was about human ear system. Figure 1 shows the long length and short length conditions. The experiment was conducted depending upon two types of task: 1) conceptual and 2) procedural tasks. Conceptual task was about the descriptions of organic functions in ear system. Procedural task was where sound should go through inside the human ear system. Conceptual task is assumed to be easier than procedural task is because there is no need to remember sequence of learning content for the conceptual task. Correlational analysis and group comparison were conducted to test the relationship of self-evaluation with the other constructs.

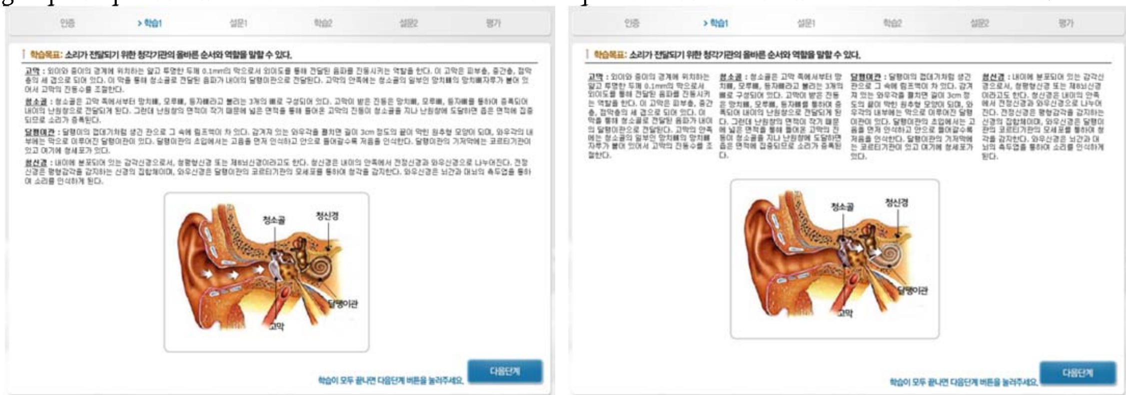

Figure 1. Long length condition (left) and short length condition (right)

Instrument

The cognitive load factor survey was implemented. It consists of 5 factors with twenty items, and 7 points Likert scale. The definition of each factor is following. Task Demand (TDE) is a psycho-physical factor that measures how much a learner invests his effort physically to solve problems. However, physical effort does not indicate work demands; rather, it is assumed to be increased mental demands required for given tasks. The general description of physical effort can be given as the amount of physical fatigue experienced in order to finish the relevant learning task. If mental demands for a task increase, learners supposedly perceive more physical effort.

Mental Effort (MEN) is the level of cognitive exertion experienced by the learner. This measurement reflects an effort factor based on learners' allocation of cognitive resources for cognitive processing. It is assumed that this factor is strongly related to germane cognitive load. If a learner inputs more effort towards learning outcomes and/or a solution, then the imposed mental effort increases. The increased cognitive load may have a positive impact on schema acquisition. If this measure increases, it is assumed that the learner's effort does as well. Generally, an increase in mental effort is evaluated as a positive exertion.

Perceived Task Difficulty (DIF) is an anticipated cognitive load caused by a given task. If a task has a high level of complexity, then learners' perception of its difficulty increases. This factor is assumed to be related to the intrinsic cognitive load of a given task. Task difficulty is very sensitive to the level of the learner's prior knowledge and expertise on a given subject matter. If the measure of this factor decreases, the learner may feel that a given task can be easily handled. However, if it increases, this may reveal that some negative effects are associated with the task.

Self-evaluation (SEV) is a personal perception of how successfully and/or efficiently a learner deals with a given problem to achieve desirable learning outcomes. The learner's subjective judgments are assumed to be an important factor for efficiency of learning. This factor is related to a learner's personal beliefs about his or her capabilities to produce the designated levels of performance. Learners, who measure highly on self-evaluation, tend to show low perceived task difficulty.

Usability (USE) measures how well the learning content is used towards the learning purpose. If a learner's perception of usability is high, it indicates that the learning content can facilitate learning or at least will not impede the learning process. When a learner is studying with a learning content with low usability, the learning content may hamper cognitive processes by increasing the unnecessary cognitive load. For this reason, this factor has a strong relationship with extraneous cognitive load.

Two cognitive efficiency measures were applied: 1) deviation model and 2) likelihood model. The formula of deviation model is the subtraction of standardized mental effort from the standardized performance. For the likelihood model, it was calculated the ratio between performance and time used to solve problem.

RESULT

The reliabilities of the instrument were evaluated for each cognitive load factors. For the conceptual task, the reliabilities were .92, .89, .85, .85, and .92 for TED, MEN, DIF, SEV, and USE respectively. For the procedural task, the reliabilities of factor were .92, .89, .85, .85, and .92 for TED, MEN, DIF, SEV, and USE respectively. It was evaluated that all of the reliabilities were acceptable.

For the conceptual learning there were significant correlations by the self-evaluation with the rest of all variables. The correlations of self-evaluation were measured with task demand (-.42**), mental effort (.59**), perceived difficulties (-.59**), usability (.56**), pre-test score (.19**), and post-test score (.19 **). For the procedural learning there were significant correlations for all of the variables. The correlations of self-evaluation were measured with task demand (r=-.42**), mental effort (r=.59**), perceived difficulties (r=-.59**), usability (r=.54**), pre-test score (r=.23**), and post-test score (r=.23 **). The results revealed that self-evaluation showed significant relationships with the rest of the constructs.

The group comparison by line length of conceptual learning was conducted with controlling the pre-test score. The results showed that there was a significant difference of the self-evaluation (F=4.78, p=.029). It indicated that learners with the long length condition had higher self-evaluation score. However, there was no significant difference in procedural learning.

For the relationship between the self-evaluation and two cognitive efficiency measures for the conceptual task, there were significant correlations. The correlations of self-evaluation were measured with deviation cognitive efficiency (r=-0.30**) and likelihood (r=0.01). For the procedural task, the correlations of self-evaluation were measured with deviation cognitive efficiency (r=-0.23**) and likelihood cognitive efficiency (r=0.11*).

DISCUSSION

Furthermore, it showed the highest correlation values with mental effort, task difficulty, and usability of learning material across the types of tasks. Particularly the self-evaluations showed negative correlation with task difficulties while it had positive correlations with mental effort and usability. This result indicated that the self-evaluation can be used to predict an overall cognitive load. However, it is not quite evident that the self-evaluation is sensitive regarding to the difficulty levels of tasks. Maillard et al., (2013) found that negative correlations between self-evaluation and cognitive load suggesting that higher cognitive load was associated with lower self-evaluation. Their findings are corresponding to the present study. The self-evaluation scores in this study showed negative correlations with the perceived difficulties for conceptual and procedural tasks. For the cognitive efficiency measures, there were some unexpected results. The self-evaluation measure showed significantly positive correlations with likelihood model but deviation model.

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