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Cognitive load in working memory on trigonometry learning

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Abstract

The cognitive process involves three elements in the human memory system; sensory, working, and long term memory. Unless the long term memory does not have enough preliminary knowledge, the working memory will have difficulties in providing meaning and constructing information as a knowledge, so the working memory is overloaded to understand the problems.With regard to that symptom, the aim of this study is to find out the cognitive load in trigonometric learning. The subjects of this study are students of grade X4 SMAN 6 Semarang. The cognitive load in working memory is caused by three sources, including Intrinsic Cognitive Load (ICL), Extraneous Cognitive Load (ECL), and Germane Cognitive Load (GCL). The results show that ICL can not be manipulated, but ICL can be well processed. Then, ECL can be minimized by material presentation techniques through the help of materials that utilize information technology media. While GCL can be improved through problem solving in developing students' mathematical creative thinking skills.

1. Introduction

Learning is a change in the knowledge composition that has been stored in memory through a process of reconstructing a new or an old knowledge (Retnowati, 2008). The degree of information acceptance on the basis of structure is a measure of process and learning outcomes. Besides, mental structure is concerned with the reception, storage, integration and retrieval of information that can be operationalized. The theoretical assumptions in learning really focus on the controlled memory and do not exceed the burden especially on short-term memory as a means of process. The exercise strategy for maintaining information can be done through metaphors and analogy which are expected as a way to reconnect old information to new one (Kuswana, 2013). In the learning environment, the main goal is to help students to learn. Piaget argues that learning is an iterative process whereby newly created information fits into existing knowledge, and can be modified to accommodate new information.

A knowledge, attitude, and skills can essentially be moved through the learning process in various ways. This transference can be seen from a general understanding, or it can be interpreted as an entirely new set of knowledge and transferred from the sender to the recipient through certain media. According to Kuswana (2013), the transfer of learning is a learning outcomes transfer from one situation to another, and one such situation is expected being able to give an effect of enhancement or support of new knowledge.

With regard to that symptom, learning transfer process involves a memory system for processing the information which is being studied. Thus, in designing an effective learning model needs to consider how the cognitive process build the knowledge. Cognitive load theory develops learning methods based on the characteristics and functions of memory systems in organizing information (Sweller, 2010).

Processing information in order to be a knowledge which is stored in human memory or knowledge processing processes in memory is also called as cognitive process. It involves three main elements in the human memory system, namely

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sensory, working, and long term memory. Shifrin and Atkinson try to reveal information processing system through the following diagram.

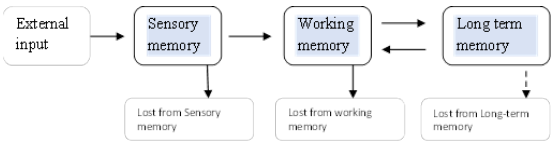

Figure 1. Atkinson and Shiffrin memory models (Matlin, 2009)

In sensory memory, the selected information is deciphered into signals to be perceived by recognizing the pattern, without understanding its meaning, using the initial knowledge in the form of a prototype, the analysis of a form. This initial knowledge determines how the memory sensory prepares the stimulus. When the attention to sense the stimulus is enhanced, the sensing means collects more unrelated information and then sends it to the next memory system that is working memory, to provide and organize the meaning of that information. However, working memory has limited capacity. It is in accordance with George Miller research who says that one can save a number of items in the short-term memory (working memory), which is about 5 to 9 elements of information at a time.

If long term memory does not have sufficient initial knowledge which is being a prerequisite to correctly interpret the information being processed, then the working memory will be difficult to give meaning and construct the knowledge into a knowledge. Consequently, the working memory is getting difficulty to understand the problem. However, if there is sufficient prerequisite knowledge to process the information, then the working memory has enough capacity to understand the problem, so there is room on the working memory that can be used to construct the solution of the problem.

Cognitive load is a mental effort that must be done in working memory to process information received at certain intervals (Sweller, 2011). Cognitive load theory (cognitive load theory) states that the strengths and limitations of human cognitive architecture derived from instructional design (Kalyuga, 2009). The main components of human cognitive architecture are working memory and longterm memory.

Furthermore, cognitive load theory is used to describe the burden of the human cognitive system when task is done (Sun, 2007). When someone gets a new information, working memory will process the information and try to keep it in long term memory. In the cognitive load theory, the load received by working memory consists of first, Intrinsic Cognitive Load (ICL) which is the burden caused by several interactivity elements that are simultaneously processed in the working memory. Second, Extraneous Cognitive Load (ECL) which is the burden caused by the instructional result which burdens the working memory in processing the information. Third, Germany Cognitive Load (GCL) is a burden caused by business results in working memory in the formation of schemes and automation intended for information relevant to new information (Kalyuga, 2009; Sweller, 2011).

Again, the cognitive load theory is part of a learning theory that tries to improve the subsequent learning (Kalyuga, 2009). Learning is a system consisting of various components that are interconnected with one another (Rusman, 2013). These components include objectives, materials, methods, and evaluations.

Mathematics is a tool for developing ways of thinking. Learning mathematics will have a cognitive developmental effect on more complex thinking skills (John, 2016). One of the mathematical materials that can form more complex thinking skills is trigonometry. In trigonometry, students learn to calculate triangles by utilizing large angles. Some students in SMA Negeri 6 Semarang complained about their lack of understanding in the study of trigonometry, this is seen in the students' daily test results.

Based on the background of the study, it is necessary to do a cognitive load research study in working memory on trigonometric learning.

2. Method

Since the aims of the study are to illustrate, explore, and find a broad perspective on the cognitive load of students in trigonometric learning, the type of study used is descriptive qualitative research.

The study was conducted on X4 students of SMA Negeri 6 Semarang with 36 students. The researcher is as the main instrument as well as the data collectors. The researcher observed the process of mathematics learning activities on trigonometric materials conducted by mathematics teacher as usual without any engineering or arrangement. It is intended that the results obtained highly describe the cognitive load in trigonometric learning.

The supporting instruments in the study consist of observation sheet filled by the observer and

arranged based on the cognitive load indicator and also the difficulties or the student's effort in the learning activity, while the student's learning journals are filled by the students which further were arranged based on the difficulties or the effort done by the students in the learning. Then the semi interview guide structured is based on the difficulties and students' efforts in learning.

Moreover, the data analysis techniques used in the study consisted of transcribing verbal data, understanding data, reducing data, coding data, drawing structures from coding, analyzing, and drawing conclusions (Creswell, 2009)

3. Results And Discussion

Intrinsic cognitive load (ICL) that students should receive in trigonometry learning is the rules of sinus and cosine on the triangle and its application in determining its area. In understanding the rules of sine and cosine students should understand the value of the comparison of trigonometry at a special angle.

In the initial learning step, the ICL appears related to the prerequisite material. The prerequisite material given to the learning relates to the ratio of trigonometric to right triangle and trigonometric ratio in various quadrants. ICL can be seen when students did not memorize in determining trigonometric comparison value at a certain angle. From difficulties experienced by students, it can be seen that the rules of sinus and cosine on the triangle is the ICL that must be processed by students.

Besides, the cognitive load is also seen in the observation results in other learning activities. From that results, it can be seen that the trigger of the interaction between students with students because of the questions/ problems given by teachers related to the ratio of trigonometric value at a certain angle, so that there were some students who have not understood and asked his classmates.

In the core activities of learning about the rules of sinus and cosine on the triangle, ICL can be seen from the difficulties and mistakes experienced by students in doing the exercises. When the teacher gave the exercise and an opportunity to a student to write the results of their work on the blackboard, the student with the initials DF was still getting difficulty in making mathematical models and confused in applying the rules of sinus and cosine.

Extraneous Cognitive Load (ECL) in the learning appears on the results of students' learning journals about ongoing learning and also reflection on the learning that is done. After learning, the students responded to some causes of the ECL source caused by the teacher in the learning activities. The learning load at the time includes quick teacher's talking tempo in explaining, as the result students hardly understand the material. In addition, the lack of class mastery from the teacher made the students were less interested in the learning. The teacher also did not really pay attention on the students' condition when the learning activity occurred. However, from the results of reflection in learning, the teacher paid more attention to students who sat in front of him, yet less attention to students who sat behind. The results of observations also show that teachers are less likely to provide opportunities for students who were less active in learning to do things in front of the class.

Germane Cognitive Load (GCL) in learning is seen through observation as well as student learning journals. The cognitive load is seen when the teacher began to explain the prerequisite material that is the ratio of trigonometric ratios in various quadrants and trigonometric charts. When explaining the graph of the trigonometric function, the teacher wrote on the blackboard manually, consequently it made the process became longer. In the observation results, it can be seen that some students followed carefully and answered the teacher's question in determining the coordinate point in making the graph. However, some students still did not understand the function of trigonometry, if its function was quickly and precisely changed.

In the theory, there are 3 cognitive load indicators, two of them tend to burden the students in learning while the rest tends to support students in learning. ICL and ECL tend to inhibit, yet GCL tends to facilitate in learning. The emergence of ICL, ECL, and GCL in learning activities affects the students' mental effort in understanding the rules of sine and cosine on triangles on trigonometric material. The high ECL trend makes learning performance worse, on the contrary with high GCL tendency which makes learning performance becomes better.

Intrinsic Cognitive Load (ICL) is determined by the complexity level of the information or material which is being studied, while the Extrinsic Cognitive Load (ECL) is determined by the technique of material presentation. The ICL cannot be manipulated because it has become the character of the interactivity of elements in the

material. Obviously it has been fixed. However, the ECL load can be manipulated. Indeed, good material presentation techniques which do not complicate understanding, will decrease ECL. Understanding of a material can easily occur if there is sufficient prerequisite knowledge that can be summoned from long-term memory. If this prerequisite knowledge can be automatically presented in the working memory, then the ECL will be minimum. The more knowledge that can automatically be used, the more minimum of cognitive load in working memory will be.

Materials that intrinsically have a heavy load, if they are well presented, then the cognitive process in working memory will run smoothly. Conversely, although ICL of a material is mild, yet poorly presented, such as too much or random, the cognitive processes in the worker's memory will proceed slowly or probably stop. If the worker's memory has been fulfilled by ICL and ECL, then there is no remaining charge for the constructive cognitive load. Above all, constructive cognitive load is a load caused by cognitive processes which are relevant to the understanding of the material which is being studied and the construction process (knowledge acquisition scheme). If there is no constructive cognitive load, it means that the worker's memory cannot organize, construct, codify, elaborate or integrate the material which is being studied as well-kept knowledge in long term memory.

4. Conclusion

Intrinsic Cognitive Load (ICL) in trigonometric learning arises from a number of interactivity elements to have to be studied and the complexity of the material which is being studied. ICL which is caused by a number of elements of interactivity is the number of material topics that must be studied into one. Elements that interact in trigonometric learning include the comparison of trigonometry in right triangles, trigonometric comparisons at special angles, trigonometric function graphs, trigonometric equations, sinus and cosine rules, formulas on trigonmetry. The complexity of the material in trigonometric learning is the difficulty in recalling trigonometric comparison values at special angles, difficulty in drawing graphs of trigonometric functions, difficulty in making mathematical models of trigonometric contextual problems, difficulty in understanding the use of sine and cosine rules. Further, ICL can not be manipulated because it has become the interactive character of elements of the material, but ICL can be managed properly.

Extraneous Cognitive Load (ECL) in trigonometric learning arises as a result of instructional design that makes students difficult to understand the material. ECL in trigonometric learning is caused by the way teachers deliver material which is too quick and is abstract as the characteristics of trigonometry and learning conditions caused by the lack of focus of some students in learning activities. So that ECL can be minimized by using media of learning based on technology and information.

Germane Cognitive Load (GCL) in trigonometric learning arises from students' attempts relevant to trigonometric understanding. GCL in trigonometric learning is caused by the way the teacher in delivering the material through problem solving in developing students' mathematical creative thinking ability.

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