The Cognitive Load Theory the Roles on Mathematics Learning in Indonesia

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Abstract-**The basic idea of cognitive load theory is that cognitive capacity in working memory is limited, so if the learning task requires too much capacity, learning will be hampered. The purpose of this study was to see how the role of learning that optimizes the use of working memory capacity and avoid cognitive overload with the use of CLT nuanced learning processes. The method used is meta-analysis and uses 15 data relating to CLT and applies statistical methods to complement other purposes. This article shows that the application of cognitive load theory is able to minimize the cognitive load process of students so as to produce effective and optimal learning and know the opportunities for application to mathematics learning.**

Keywords: cognitive load theory, instrinsic load theory, extraneous load theory, German load theory

I. INTRODUCTION

Memory is defined as the ability to encode, store, maintain and remember information and past experiences in the human brain. Most of the information is stored for future control in motor activities and for use in thought processing. There are 3 types of memory, namely: short term memory, long term memory, and working memory. Baddeley et al (1974) mention working memory is responsible for processing information and following up on that information and is very important for the learning process (Pass, et al: 2014).

Working memory can only store about four to seven items or pieces of information at a time (Miller, 1956; Baddeley, 1986; Cowan, 2001; Paas et al, 2014). When processing information (organizing, showing differences, and comparing), humans can only manage two or three items of information simultaneously, depending on the type of processing needed (Kirschner, Sweller, & Clark, 2006). So that new information stored in working memory if untrained is lost in about 15 to 30 seconds (Peterson-Peterson, 1959; Driscoll, 2005; Cowan, 2014; Paas, et al. 2014).

Basically, learning will be hampered when the working memory capacity is exceeded in the learning task (de Jong, 2009). To support increased learning effectiveness and optimize learning, it is recommended to reduce cognitive load that is not necessary for working memory. Cognitive load theory distinguishes three types of contributions to the total cognitive load. Intrinsic cognitive load relates to the inherent characteristics of the content to be studied, extraneous cognitive load is the burden caused by instructional materials used to present content, and German cognitive load refers to the burden imposed by the learning process (Van Merrienboer & Sweller, 2005; de Jong, 2009; Plass, JL, et al, 2010).

Based on the above review, this paper will look at the role of cognitive load theory in learning that optimizes the use of working memory capacity, with the following research questions: 1). what is meant by cognitive load theory; 2). how the application of cognitive load theory to learning in schools; 3). how the impact of the application of cognitive load theory to learning; 4). What are the opportunities for developing cognitive load theory in mathematics learning?

II. METHODS

The research method uses the meta-analysis method, using a considerable amount of data and the application of statistical methods by practicing and organizing a number of information that comes from a large sample and serves to complement other purposes (Glass, 1981). The database used came from the ERIC Institute of Education Sciences, the Garuda Portal, Researchgate, google scholar and manual searches. Articles used as data are restricted from 2015 to 2019. The first stage of the search using the cognitive load theory keywords found 274 articles, but with descriptors teaching methods there are 83 articles. Then narrowed down only to schools in Indonesia so that the data is directed to 15 articles discussed.

III. RESULTS AND DISCUSSION

Based on the research questions raised, the writer tries to discuss the research questions one by one. Starting with the first question.

Cognitive Load Theory

Research on Cognitive Load Theory began to be introduced in the late 1980s and early 1990s, then used in various educational studies at this time (Chandler & Sweller, 1991; de Jong, 2009). Cognitive load theory is based on the idea that our working memory has a limited capacity to process new information from the environment (Russo & Hopkins, 2017), but it can access large amounts of previously processed and organized information from long-term memory (Baddeley, 1992). Based on this we can say that cognitive load theory explores the instructional consequences of our limited working memory capacity to produce effective and optimal teaching and learning process.

Basically, cognitive load theory asserts that learning is inhibited when working memory capacity is exceeded in learning tasks. Cognitive load theory can be caused by three sources, namely: intrinsic cognitive load, extraneous cognitive load, and germane cognitive load (de Jong, 2009; Plass, J.L., et al, 2010; Sweller 2010). intrinsic cognitive load relates to the inherent characteristics of the content to be studied, extraneous cognitive load is the burden caused by instructional material used to present the content, and germane cognitive load refers to the burden imposed by the learning process.

Intrinsic cognitive load depends on the level of difficulty of a material and is not influenced by external factors (Cooper, 1998; Sweller & Chandler, 1994; de Jong, 2009) but with good presentation techniques and does not complicate student understanding, and start material that is simple to complex it will be managed intrinsic cognitive load (van Merrienboer et al. 2003). Extraneous cognitive load is generated by instructional material, depending on the presentation of the material. It also deals with the formation of schemes and automation but can be changed by the instructional intervention (van Merrienboer and Sweller, 2005). Whereas Germane cognitive load is a relevant or beneficial burden imposed by teaching methods that lead to better learning outcomes. The main focus of Germane cognitive load is to see the construction of the scheme and subsequently automation as the main objective of learning (Sweller, 1988). Schema development involves processes such as interpreting, modeling, classifying, summarizing, differentiating, and organizing (Mayer 2002). For this reason, learning design must try to stimulate and guide students to be involved in the construction of schemes and automation, in this way striving to increase Germane cognitive load.

In learning, cognitive overload depends on the level of difficulty of the material being studied according to intrinsic cognitive load. If the material being studied is intrinsic cognitive load high, the learning design must be organized so that extraneous cognitive load can be reduced to a minimum.

Application of Cognitive Load Theory in Learning in Schools

The description of cognitive load theory explains that to be able to streamline the teaching and learning process, one must pay attention to three sources, namely: intrinsic cognitive load, extraneous cognitive load, and germane cognitive load. According to cognitive load theory teaching and learning process will be more effective if you pay attention to each cognitive load, namely by minimizing extraneous cognitive load, increasing germane cognitive load, and managing intrinsic cognitive load.

Cognitive learning theories emphasize mental processes that cannot be observed and used by people to learn and remember information or new abilities (Slavin, 2009) so that they feel it will be suitable when used in the learning process. This motivates a lot of research in Indonesia that focuses on the learning process by emphasizing the use of cognitive load theory which is expected to increase the effectiveness of learning outcomes and the learning process.

The application of cognitive load theory sources in learning based on analyzed research articles shows that from 15 articles from research in Indonesia the tendency to use methods or strategies based on cognitive load theory and analysis to be able to describe cognitive load for certain understanding.

The following describes the analysis of the article which is divided into several categories below:

a. Identify research needs for cognitive load theory

Table 1: Identification Of Needs About Cognitive Load Theory

Needs	Frequency
Analysis of learning using CLT	9
The use of certain learning methods / strategies based on CLT	3
The use of certain learning media based on CLT	3

Based on the identification of the 15 articles analyzed showed that among the use of methods/strategies/approaches, the use of nuanced media, analysis of learning based on CLT was considered to have the most frequency in his research which was 9.

b. Research objectives analyzed

The research objectives identified about CLT research from 15 articles focus on describing the ability of understanding concepts based on CLT, to students. Indicators of ability to measure tendencies about understanding the rest of the concepts of problem-solving skills, mathematical literacy and others that are not clearly stated in the analyzed article.

c. *The research method being analyzed*

Research on CLT analyzed from 15 articles shows that there are 5 methodological variations, namely experiment, research, and development, qualitative, descriptive, quantitative. The most methods of research are the highest number of Research and Development 5 and the least are experiments, namely 1. For more details, it is described in Table 2.

Table 2: Research methods in Analysis

Methodology	frequency
Experiment	1
Research and development	5
Qualitative	3
Descriptive	3
Quantitative	3

d. *Collection of research data analyzed*

The collection of data analyzed based on article data, the tendency to see results in students using the essay format. This can be seen from Table 3, that the frequency to measure student outcomes is 9.

Table 3: Data Collection

Data Collection Tools	Frequency
Questionnaire (Likert type)	13
Interview	2
Document analysis	1
Observation	5
Rubric	13
Worksheet	1
Essay	14
Recording Video	1

e. *Sample*

The sample in this study is in the range of elementary school students to the tertiary level. It is possible that cognitive load especially its management is needed for each level of education and is very relevant for the study. Of the 15 articles analyzed, the highest sample for the high school category is possible at the high school level of high cognitive load level, while article 2 does not mention the sample of research in which the school category.

Table 4: Sample Research

Data collection tools	Frequency
Primary school	2
Junior high school	1
Senior High School	8
College	2
Unknown	2

The Impact of Cognitive Load Theory on Learning

The impact of applying cognitive load theory to learning based on the analyzed articles shows that the CLT tendency is able to make teaching and learning effective and improve student learning outcomes. 15 articles analyzed 7 of them mentioned that the use of CLT in learning is able to manage intrinsic cognitive load, reduce extraneous cognitive load, and increase germane cognitive load. Table 5 shows the learning outcomes using CLT from the analyzed article.

Table 5: Improved Learning Outcomes

Impact on students in improving learning outcomes	Frequency
Concept Understanding	7
Academic Emotions	1
Mathematical Anxiety	2
Mathematical Literacy	3
Problem solving skills	2

Development Opportunities in Cognitive Load Theory in Mathematics Learning

Research in the CLT nuanced learning process allows many to use a variety of methodologies, sampling, and also the realm of research subjects may still be explored further. The studies analyzed show quite varied results for the learning process. The impact of the learning process based on analysis can also be concluded that CLT is also able to manage intrinsic cognitive load, reduce extraneous cognitive load, and increase Germane cognitive load, can improve student learning outcomes, especially understanding concepts and ability to solve problems but very few discuss the ability procedural.

Based on the descriptions above, it can be assumed that the opportunities that we can do for research in mathematics education are: first, the use of media in the learning process using CLT for better learning outcomes, because the purpose of designing multimedia learning media is to reduce extraneous cognitive load processing, regulate intrinsic cognitive load processing, and help develop germane cognitive load processing (Mayer & Moreno, 2010).

Second, referring to the 2013 curriculum objectives that are currently in effect in Indonesia, the expected curriculum goals include character, literacy, and competence. In line with this when we look at

21st-century skills consisting of four main domains, namely: literacy, inventive thinking, effective communication and high productivity (Omar, Turiman, Daud and Kasman, 2011). Thus we know that literacy is very encouraged at this time.

Opportunities that can be developed are the CLT learning process (Asmara, et al, 2019) for mathematics literacy skills because Indonesia has always been ranked 10th lowest (2009-2015) in literacy abilities according to the OECD which assesses literacy skills based on PISA (International Program for Student Assessment), the average international score of ability literacy is 500 (level 3), while the average literacy score of Indonesian students is 375 (level 1), level 1 is the lowest level of the six levels of literacy ability set by PISA and the highest level that Indonesian students can achieve is level 3 (OECD, 2014; Wardono et al, 2016; Asmara, 2017) and some students are at level 4 (Edo, et al, 2013).

Ojose, B (2011) states that mathematical literacy is knowledge to know and use a mathematical basis in everyday life. In this sense, someone who has good mathematical literacy skills has a sensitivity to mathematical concepts that are relevant to the problem at hand. From that sensitivity then proceed with problem-solving using mathematical concepts.

Another opinion shows that literacy in the context of mathematics is the power to use mathematical thinking in solving everyday problems to be better prepared to face life's challenges (Steecey & Turner, 2015). The intended mathematical thinking includes problem-solving mindset, logical reasoning, communicating and explaining. This mindset is developed based on mathematical concepts, procedures, and facts that are relevant to the problem at hand (Rosalia, 2015). The literacy domain listed in PISA-D includes content, context, and process (OECD, 2017). The process domain is divided into three indicators with a range of different activities for each indicator.

The description above states that the studies to be carried out relating to CLT with literacy skills are considered suitable because mathematical literacy encompasses content, processes, and contexts so that the final results obtained by students are not only knowledge, but problem-solving and also procedural abilities used. And based on the analysis of data that has been explained the tendency with CLT nuanced learning can optimize these results.

IV. CONCLUSION

This article discusses the role of CLT in the learning process so that it is able to manage intrinsic cognitive load, decrease extraneous cognitive load, and increase germane cognitive load, can improve student learning outcomes, especially understanding concepts and ability to solve problems but very little is discussed about procedural abilities.

There are several opportunities that can be developed for further research, such as competency skills other than understanding concepts, for example, is mathematical literacy that is suggested by the current curriculum objectives 2013, as well as the use of media in learning with CLT nuances.

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