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Finding Matrix Concepts Based on Cognitive Load Theory On Mathematics Learning Ability to Improve Mathematics Literacy

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Abstract

This research aimed at improving mathematical literacy among vocational high school students. The subject was students in class X. This qualitative research used tests, observation sheets, questionnaires, and interviews. The result shows that there was a limitation in our brain to process complex contents. Therefore, according to cognitive load theory, in the studying process, the teacher should minimize intrinsic cognitive load and stimulate germane cognitive theory, thus improving students' literacy.

Keywords*: Cognitive Load Theory; Mathematical Literacy; Vocational High School Students*

1. Introduction

Studying mathematics is one of the means to think logically and systematically. The role of learning is not only to educate students, but also to shape the personality of students who are disciplined, timely, responsible, and able to think scientifically. As expressed by Ausubel (Dahar, 2006) which emphasizes that the learning process is poor in terms of student involvement and the essence of the content being studied, it causes students not to get a complete, comprehensive, and comprehensive understanding so that students quickly forget it. In other words, when we want to create learning it must combine knowledge to be applied in daily life, as stated by Steen & Turner (2007) which states that the ability to use mathematical knowledge and understanding must be effective in everyday life or better known as literacy mathematics. Based on this, it is very clear that knowledge and understanding (content and context) about mathematics is very important, but more importantly, it can apply mathematical literacy to solve problems in everyday life (De Lange, 2003; Brombacher, 2007; Bansilal & Debba, 2012; Colwell & Enderson, 2016).

Asmara (2017) in his research on the analysis of students' mathematical literacy skills based on mathematical abilities, revealed that most students were able to answer problems with clear questions, identifying information, work on basic algorithms, use formulas, implement procedures or agreements, give exact reasons for results completion, interpret, and recognize situations with contexts that require direct conclusions (level 1, 2, and 3 mathematical literacy).

The results of the PISA (International Program for Student Assessment) study found that the average international score of mathematical literacy skills was 500 (level 3), while the average score of Indonesian mathematics literacy was 375 (level 1), level 1 was the lowest level of six the level of mathematical literacy abilities set by PISA. The level of indicators of mathematical literacy skills according to PISA are:

Table 1. Summary descriptions of the six proficiency levels in mathematics

Level	What students can typically do at each level
6	**At Level 6**, students can conceptualize, generalize, and utilize information based on their investigations and modeling of complex problem situations, and can use their knowledge in relatively non-standard contexts. They can link different information sources and representations and flexibly translate among them. Students at this level are capable of advanced mathematical thinking and reasoning. These students can apply this insight and understanding, along with a mastery of symbolic and formal mathematical operations and

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Level	What students can typically do at each level
	relationships, to develop new approaches and strategies for attacking novel situations. Students at this level can reflect on their actions and can formulate and precisely communicate their actions and reflections regarding their findings, interpretations, arguments, and the appropriateness of these to the original situation.
5	**At Level 5**, students can develop and work with models for complex situations, identifying constraints, and specifying assumptions. They can select, compare, and evaluate appropriate problem-solving strategies for dealing with complex problems related to these models. Students at this level can work strategically using broad, well-developed thinking and reasoning skills, appropriate linked representations, symbolic and formal characterizations, and insight about these situations. They begin to reflect on their work and can formulate and communicate their interpretations and reasoning.
4	**At Level 4,** students can work effectively with explicit models for complex concrete situations that may involve constraints or call for making assumptions. They can select and integrate different representations, including symbolic, linking them directly to aspects of real-world situations. Students at this level can utilize their limited range of skills and can reason with some insight, in straightforward contexts. They can construct and communicate explanations and arguments based on their interpretations, arguments, and actions.
3	**At Level 3**, students can execute clearly described procedures, including those that require sequential decisions. Their interpretations are sufficiently sound to be a base for building a simple model or for selecting and applying simple problem-solving strategies. Students at this level can interpret and use representations based on different information sources and reason directly from them. They typically show some ability to handle percentages, fractions, and decimal numbers, and to work with proportional relationships. Their solutions reflect that they have engaged in basic interpretation and reasoning.
2	**At Level 2**, students can interpret and recognize situations in contexts that require no more than direct inference. They can extract relevant information from a single source and make use of a single representational mode. Students at this level can employ basic algorithms, formulae, procedures, or conventions to solve problems involving whole numbers. They are capable of making literal interpretations of the results.
1	**At Level 1** students can answer questions involving familiar contexts where all relevant information is present and the questions are clearly defined. They can identify information and to carry out routine procedures according to direct instructions in explicit situations. They can perform actions that are almost always obvious and follow immediately from the given stimuli.

OECD, 2014

Based on this, the tendency of students is only able to manage the information received at that time but it is difficult to process all information and save it into understanding for a long time. This is possible because there are too many concepts that must be remembered and processed by students so that the effectiveness of learning is not optimal. For this reason, a method is needed to reduce the concepts students must remember.

Cognitive Load Theory (CLT) is a technique to reduce memory burdens (concepts) in students. Sweller (1994) revealed that the principle of this theory is that the quality of learning will increase if attention is concentrated on the role and limitations of working memory. 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 of motor activities and use in thought processing. Miller (Nursit, 2015) mentions that working memory can only store about 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 not trained is lost in about 15 to 30 seconds (Peterson-Peterson, 1959; Driscoll, 2005; Cowan, 2014; Paas, et al. 2014).

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Cognitive load theory in working memory can be caused by three sources, namely: intrinsic cognitive load, extraneous cognitive load, and germane cognitive load (Chandler and Sweller 1991; Sweller, 1994, 1989; Sweller et al., 1990; Plass, et al., 2010). Intrinsic cognitive load is fixed and innate for the task so that it is not influenced by external factors, depending on the level of difficulty of the material, but with good presentation techniques and does not make it difficult for students to understand intrinsic cognitive load (Ayres, 2006b). As expressed by Sweller & Chandler (1994) that intrinsic cognitive load is determined by the level of complexity or difficulty of the material being studied. Intrinsic cognitive load cannot be manipulated because it has become the character of the interactive elements in a material, so it is constant (Sweller, et al. 2011).

Extraneous cognitive load depends on the presentation of material (Sweller & Chandler, 1994) and matters related to factors that must be minimized in learning, such as the use of confusing teaching materials, noise, and display of computer media that have too much animation. Whereas germane cognitive load is a relevant or beneficial burden imposed by teaching methods that leads to better learning outcomes. In learning, cognitive overload depends on the level of difficulty of the material studied according to intrinsic cognitive load. Based on this, it can be said that effective learning lies in cognitive load optimization in the limited working memory capacity of students If the material studied by an intrinsic cognitive load is high, learning design must be organized so that extraneous cognitive load can be minimized as much as possible. Therefore, in this study, researchers will process the mathematics learning of vocational students based on cognitive load theory to improve mathematical literacy skills because by knowing the characteristics of CLT, it is likely that learning outcomes are expected to increase and be able to solve problems related to mathematics (Damayanti, 2013; Fitriyah, et al., 2014; Kristiana, 2015).

2. Method

The approach used in this study is qualitative. The research subjects were class X Vocational students. In this study, the achievement of student indicators for each level of mathematical literacy after mathematics learning on sub-material found the concept of space-based on cognitive load theory.

The data analyzed in this study include: student worksheets to see intrinsic cognitive load carried out during the learning process. The observation sheet, questionnaire, to see Extraneous cognitive load, were carried out at the end of learning and interviews to see how the relationship between intrinsic cognitive load Extraneous cognitive load. Interviews were conducted on only 6 students, taken from 2 students who had the highest score, 2 people in the medium category, and 2 others in the low category (scores based on the formative test results). Formative repeat type essay test with the level of literacy ability indicator to see a germane cognitive load.

Research is carried out through three stages, namely: planning, implementation, and evaluation, or reflection. The steps taken in the research are based on cognitive load theory, namely: determination of Core Competence (KI), Basic competencies (KD), learning objectives, identification of student characteristics (initial ability, interest, motivation), determining the subject matter, determining the topic of study, developing learning materials in the form of worksheets students, examples and so on, arrange the topic of the lesson from easy to difficult, from simple to complex, from concrete to abstract, as well as assessing the results of learning and reflection to be able to see the extent of learning effectiveness and to know things which need to be followed up.

3. Results and Discussion

From the results of the data analysis, it was found that at the preparation stage there was an extraneous cognitive load, one of which was the lack of preparation of some students so that at the beginning of the learning process it caused the noise. While intrinsic cognitive load can be managed properly. This load cannot be reduced because it depends on how complex the material is being studied. According to cognitive load theory, this burden can only be managed like delivering material in a coherent, structured, from simple to complex.

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Whereas germane cognitive load will not increase if the teacher does not convey the preconditions. The formation of new concepts will not be obtained by students if students cannot connect the new information received with what they already have. This depends on how the teacher designs the learning process so that it can be realized. The results above show that there is a cognitive burden student have, which can be seen from the learning process (Table 2).

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Table 2. Description and Learning Steps

No	Learning Activities	*Cognitive Load Theory*	Literacy Ability Level
1	Observing and asking questions • Presentation of context • Productive questions • Read the literature, serves to focus on solving problems	• This stage is prone to extraneous cognitive load because if the teacher does not pay attention to the conditions of readiness (confusion) of students, it is likely that students are vulnerable to losing interest and motivation to learn. • if not supported by prerequisite capabilities, the germane cognitive load will not increase and the possibility of the material can only be short-term memory. • *intrinsic cognitive load* masih relatif rendah, dan bisa di ukur melalui angket.	• Answering questions in a known context and all relevant information available with clear questions. • Identifying information, and perform general ways based on clear instructions. • Shows an action according to the simulation given.
2	collecting Information • Identify the problem • Gathering answers from problems through literature, observation, and others • Find assumptions and hypotheses	• Germane cognitive load is very likely to be enhanced by the interrelationship of the material already possessed with new information • intrinsic cognitive load begins to increase, at this stage the teacher must be able to manage the concept well and limit its scope • with increasing intrinsic load extraneous cognitive load tends to increase because if students feel the intrinsic burden is too high (especially students in the medium and low categories) they tend to be unable to do anything	• Identify information, and carry out general methods based on clear instructions. • Show an action according to the simulation given. • Sort out relevant information
3	Associate and Communicate • Processing data • Find the hypothesis answer • Communicate results	• The association stage of intrinsic cognitive load is at its peak because all material has been given to prove it • The cognitive load is at its peak because students are asked to provide answers to hypotheses that have been made	• Interpret and recognize situations with contexts that require direct conclusions. • Give reasons precisely from the outcome of the settlement. • Interpret and use representations based on different sources of

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No	Learning Activities	*Cognitive Load Theory*	Literacy Ability Level
		• The extraneous cognitive load needs to be pressed because students already have 2 loads • Tending to communicate, the cognitive burden decreases.	information and state the reasons directly. • Work effectively with models in concrete but complex situations that might involve restrictions to make assumptions. • Communicate the results of interpretation and their reasons. • Explain and communicate it with arguments based on their interpretations and actions.

The table above shows that intrinsic cognitive load is very large when starting learning at the stage of observing and asking, but along with the learning process, the tendency of intrinsic cognitive load decreases when communicating the results. This is because the teacher at the initial stage gives apperception by asking productive questions to find out the initial abilities of students. After all, initial knowledge will influence ICL (Moreno & Park, 2010). because the use of initial knowledge together with optimal intelligence is useful in processing information (Plass et al., 2010) which ultimately alleviates intrinsic processing in students.

Based on the data, that in this study, students still experience cognitive burdens, but this is still in the fairness stage. So that the learning process can still be optimized for mathematical literacy skills. When researchers know the cognitive load possessed by students, then as much as possible and as optimal as possible to be able to improve mathematical literacy skills because learning will be optimal when active learning builds a coherent representation of knowledge in limited working memory capacity (Moreno, 2006). And this is proven to be able to improve mathematical literacy skills based on the results of formative tests that have been analyzed.

The formative test results analyzed also showed an increase in mathematical literacy skills, as evidenced from the beginning to the end. From students who are only able to answer questions with known contexts, identifying information, and perform general methods based on clear instructions, show actions following instructions to increase to interpret and recognize situations with contexts that require direct conclusions with the right reasons, interpret and use representations based on different sources of information and expressing their reasons directly, acting with concrete modeling based on the assumptions formulated, and communicating the results of interpretation and reasons for argumentation based on their interpretations and actions. because the ability to analyze as described above is the highest cognitive ability because it can solve information into several parts that are finally assembled into a piece of meaningful information (Lawson, 1995).

Overall, it can be seen that the teacher can manage the class well, good preparation, good planning, and good evaluation. Thus, students' cognitive load can be suppressed and still exist in the normal category. This will help students to manage their activities. It is expected that students become disciplined in managing time, are responsible, and can understand every material delivered by the teacher in long-term memory (long-term memory). However, due to the limitations of the human brain in processing complex material, cognitive load theory suggests that the presentation of material should minimize intrinsic cognitive load, and more stimulate Germane cognitive load (Sweller & Chandler, 1994).

In other words, when the complexity of the material is quite complex, the teacher must continue to strive so that the material can still be understood by students. Although there is much that the teacher has to do, such as making an analogy to convey the material (using an

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easily understood context), the use of optimal learning media such as the use of video or PowerPoint can also open up initial knowledge that has an impact on decreasing intrinsic value and also coherent delivery and using learning methods or models that are tailored to the characteristics of the students themselves to improve the results of the german load.

From the management of intrinsic cognitive load performed, different results were obtained for male and female students. Female students tend to have better grades, more manage time, and discipline in carrying out tasks. Most male students tend to be able to do the learning process with logic and context to obtain new information (related to Germane cognitive load). This is in line with Higbee and P.V's research. Thomas (1999) who revealed factors that influence achievement in mathematics, including gender, beliefs, attitudes, and emotions such as self-confidence, anxiety, interest, and desire to do or understand things, relevance to student life, previous mathematical experience, as well as learning styles and strategies.

4. Conclusions and Recommendations

Intrinsic cognitive load occurs in students because of the complexity of the material preconditions and the many elements of material and social interactivity. Whereas germane cognitive load occurs in students because the method and design of learning are relevant to the objectives of the ability at the expected level of literacy. And extraneous cognitive load occurs in students because of the teacher's way of conveying apperception (eg with productive questions that should open up students' initial knowledge of the material to be discussed), discussion and provision of material, (use of learning tools and media), learning techniques, psychological state of students (nervous, tense, not confident, interest and motivation), as well as disorders that come from outside of learning, such as noise in the classroom, or noise that comes from the environment. In further research, it is necessary to strive to minimize intrinsic cognitive load and maximize germane cognitive load in the learning process, as well as strive for other material to see the effectiveness of improving mathematical literacy.

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