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Pre-service Teacher Extraneous Cognitive Load in the Pedagogical Content and Knowledge of Solar System Course

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Abstract. This study reported the student's Extraneous Cognitive Load (ECL) in the Pedagogical Content and Knowledge of solar system Course. Participants in the study were 31 pre-service elementary school teachers from the university in Bogor Indonesia. The data collected from ECL were obtained using a Likert 4-scale questionnaire and interview. After taking lectures, we asked for some mental effort from pre-service elementary school teachers to attend courses in order to assess the ECL. The courses include 3 topics and they were non-experimental worksheet, developing experimental worksheet using Vee Diagram framework, and analysis for curriculum by grade IV, V and VI. Results of the data analysis showed that the course strategy resulted by ECL was relatively low. The ECL increased in the course of curriculum analysis due to material complexity.

1. Introduction

Courses for the Pre-Service Teacher students should emphasize more on how to do a good learning such as exploring knowledge, finding information, referring to the literatures, making good experiments, making inferences, interpreting and communicating [1]. One of the learning problems for the Pre-Service Teacher students is their still-low pedagogical content and knowledge for lecturing materials, especially in solar system course. On solar system course, the Pre-Service Teacher students must be able to integrate the solar system materials with its influence on human life. How low the ability of conceptual integrity is related to the capabilities of Pre-Service Teacher students in processing the information received while studying the course material, when both attending the on-going lecturing and studying the material course from various sources. Integrated learning has the positive impact for the learning results [2,3,4]. Improvement in learning results for science and science education can be implemented by integrating approaches [2], strategies [4], methods [5], and contents [3].

Basically, learning process is related to the memory capacity in receiving information. Each person has different limited memory capacity in receiving information compared to one another. Because of the limited memory capacity, it will be heavy and become a burden for anyone when he or she has to receive a lot of information. This has also been described in Cognitive Load Theory (CLT). CLT aims at predicting the learning result by considering the capability and the limitation of human cognitive conception. This theory can be applied in a variety of learning environments because the characteristics of teaching material design are related to the human information processing principles. Considering the demand for cognitive resources induced by the information complexities that will be



studied, then CLT aims at predicting what makes learning success and how the learning can effectively be supported by teaching and instruction [6].

As a learning theory, CLT elaborates the instructional implications for the characteristics of human cognitive conception. According to CLT, an effective and efficient cognitive conception design has working memory burdens stored in its capacity limit. This can be obtained by removing or reducing the less important cognitive activities for those Pre-Service Teacher students in which it is so-called Extraneous Cognitive Load (ECL).

A variety of researches in Natural Science applying the cognitive load theory used multimedia, especially for the abstract concept [7,8]. The applied strategies in learning made use of multimedia, namely using pedagogic agents [8], narration by pedagogic agents [9] steering questions [10], multi-display [11], annotated texts [12], social tagging in web-based learning [13], dual-modal [14,15], and independent modules [7].

Based on the opinions from Sweller [16] and Mayer [17], it is important to provide the pre-service teacher in learning by integrating the relevance of solar system materials with its influence on human life materials epistemologically, as well as developing positive behaviors and perceptions in Elementary School Natural Science Learning course in order to reduce the cognitive burdens for the pre-service teachers. The research to measure the effective CLT application needs implementing to the cognitive burdened components. ECL measurement is implemented by the mental efforts from the pre-service teachers required in lecturing.

2. Method

The observed subjects in this research were the Elementary School Pre-Service Teacher students from one of colleges in Bogor studying at Semester 5 of Year 2016/2017 whereas they are 31 students. Collected data were the qualitative ones required in answering the ECL issues for the Pre-Service Teacher students in the pedagogical content and knowledge of solar system course. The data were obtained by observation and questionnaire techniques. The observation was carried out to filter the data regarding the lecture strategies and it was implemented to the lecturers and Pre-Service Teacher students during the lecturing process, while the questionnaires were given to the Pre-Service Teacher students in order to obtain the data regarding the mental efforts in the pedagogical content and knowledge of solar system course.

3. Result and Discussion

3.1. The implementation strategy for the pedagogical content and knowledge of solar system course

The implementation strategy for solar system lecture applying the pedagogical content and knowledge of solar system is filtered through observation and field notes during the lecture implementation. The observation activity was carried out in three face-to-face lecturing on the subject of making non-experimental Student Worksheet (LKS), making experimental Student Worksheet in the framework of Vee Diagram, and Elementary School curriculum analysis for grades IV, V and VI.

Based on the observation and field notes of the implementation for the pedagogical content and knowledge of solar system course, it has been found out that the sequence of lecture steps as a lecturing strategy. The lecture steps in the subject of making the non-experimental Student Worksheet are questioning, practicing to make productive and open questions, using the Think-Pair-Share Cooperative Learning Model, discussion in determining the Student Worksheet's components, and assignment of making non-experimental solar system Student Worksheet. The lecture steps in the subject of making experimental Student Worksheet using the framework of Vee Diagram are assignment in group to bring the Elementary School Practical Student Worksheet (1 week before the lecturing activity), explanatory note for the assessment rubrics using Vee Diagram, demonstrating in assessing the Student Worksheet using Vee Diagram classically, practicing to assess the Student Worksheet using Vee Diagram rubrics, assignment in group for the Student Worksheet trial test in assessing the functioning of the worksheet resulting the concept, discussion for the Student Worksheet assessment and its trial test results, and reflection and remedial for the Student Worksheet assessment

results. Also, the sequence of lecture steps in the subject of Elementary School curriculum analysis for grades IV, V and VI are assignment in group (2 people) to find literatures regarding the Natural Science content, the Elementary School learning journal articles (in Indonesian) and the relevant article (in English), this assignment in group given 1 week before the lecture implementation, minimal concept analysis and analysis of strategy in the chosen Basic Competence (KD), analysis of thinking ability, Science Process Skills (KPS), behavior and psychomotor whose potentials to develop in the chosen Basic Competence, discussion, and designing for learning based on Basic Competence and article search findings.

3.2. *The mental effort profile of the Elementary School Pre-Service Teacher students the pedagogical content and knowledge of solar system course*

The mental efforts of the Elementary School Pre-Teacher students in the pedagogical content and knowledge of solar system course are filtered using the questionnaire (questionnaire sheet). The questionnaire sheet is used to measure the students' mental efforts in making non-experimental Student Worksheet, making experimental Student Worksheet using Vee Diagram framework, and Elementary School curriculum analysis for grades IV, V and VI.

The questionnaire sheet contains the statements expressing the compatibility between lecturing strategy with lecture materials delivered to the students. The Score for the ability to analyze is conversed into the qualitative form referring to the categorization by Arikunto [18].

Table 1. Mental effort instrumental scoring rubric

Score	Category
4	Very favorable
3	Favorable
2	Less favorable
1	Unfavorable

The Rubric at Table 1 is used to obtain the mental effort score and the score describes the easiness for the students to attain the lecturing process.

Table 2. Mental effort categorization

Score	Conversion Scale 100	Qualitative Category
$3,40 < x \leq 4,00$	$80 < x \leq 100$	Very low
$2,80 < x \leq 3,40$	$60 < x \leq 80$	Low
$2,20 < x \leq 2,80$	$40 < x \leq 60$	Average
$1,60 < x \leq 2,20$	$20 < x \leq 40$	High
$1,00 < x \leq 1,60$	$0 < x \leq 20$	Very High

In the Table 2, there is a categorization used to categorize the mental efforts of the Elementary School Pre-Service students. The conversion score is used to obtain the 100 scale value in order that all values obtained in this research has the ones with the same scale.

Based on the questionnaire result given to the Elementary School Pre-Service Teacher students in the IPA and Pedagogy contents integrated lecture in the subject of making non-experimental Student Worksheet, the obtained result is the very-low mental efforts found very dominant compared to the low ones. The category percentage of the Elementary School Pre-Teacher students in the subject of making non-experimental Student Worksheet is displayed in Figure 1.

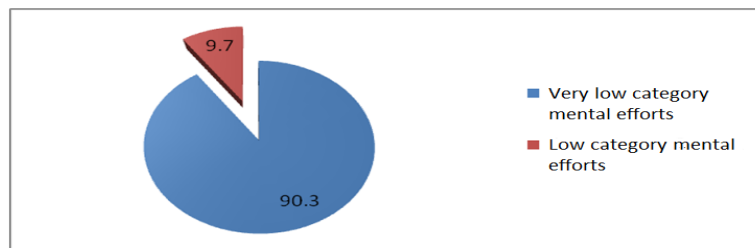


Figure 1. Diagram of the mental effort of elementary school pre-service teacher students in the subject of making non-experimental student worksheet

Figure 1 showed the Elementary School Pre-Service Teacher students' mental efforts in the subject of making non-experimental Student Worksheet is 90.3% belonged to the very-low category and 9.7% belonged to the low category.

Based on the questionnaire result given to the Elementary School Pre-Service Teacher students in the pedagogical content and knowledge of solar system course in the subject of making experimental Student Worksheet using Vee Diagram framework, the obtained result is the very-low mental efforts found larger than the low ones. The category percentage of the Elementary School Pre-Teacher students in the subject of making experimental Student Worksheet using Vee Diagram is displayed in Figure 2.

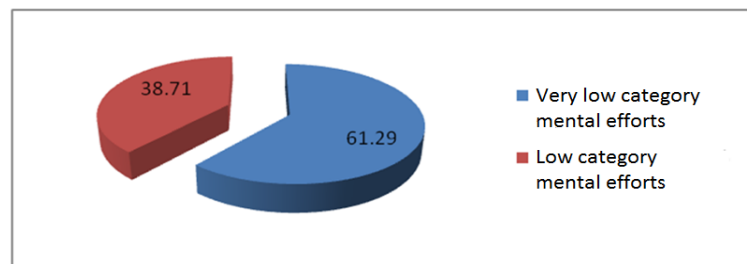


Figure 2. Diagram of the mental efforts of elementary school pre-service teacher students in the subject of making experimental using vee diagram

Figure 2 showed 61.29% at the very-low category and 38.71% at the low category. Based on the questionnaire result given to the Elementary School Pre-Service Teacher students in the pedagogical content and knowledge of solar system course in the subject of the Elementary School curriculum analysis grade IV, V and VI, the obtained result is the low mental efforts found larger than the very-low and average ones. On the contrary, the mental efforts at the very low and average categories have the same percentage. The category percentage of the Elementary School Pre-Teacher students in the subject of the Elementary School curriculum analysis for grades IV, V and VI is displayed in Figure 3.

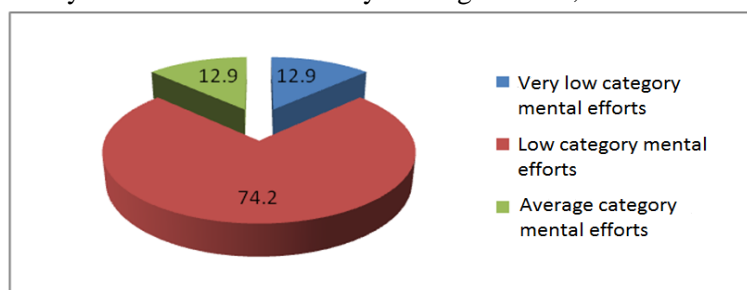


Figure 3. Diagram of the mental efforts of elementary school pre-service teacher students in the subject of the elementary school curriculum analysis for grades IV, V, and VI

Based on Figure 3, the mental efforts from the Elementary School Pre-Service Teacher students in the subject of the Elementary School curriculum analysis for Grades IV, V, and VI is 12.9% at the

very low category, 74.2% at the low category and 12.9% at the average category. It showed the decrease of the students' mental efforts at the face to face lecture in the subject of the Elementary School curriculum analysis for grades IV, V, and VI, whereas there are the average-category mental efforts as large as the very low ones. Also, the percentage of the low-category mental efforts exceeds the very low category one.

Mental effort describes the work of students' working memory in processing information. The mental effort is measured by the questionnaire given at the end of lecture during one semester. In this research, the mental efforts for Pre-Service Teacher students are categorized low if the Pre-Service Teacher students feel easy to understand their friends' explanations and to understand the materials. A mental effort is stated high if the components are considered difficult. All the students' responses are averaged per material. From the Figure 4, it can be seen the average of the Pre-Service Teacher students' mental efforts for every material so that it can be seen which material considered easy or hard.

In average, the mental efforts for the Elementary School Pre-Service Teacher students in the subject of making non-experimental Student Worksheet, making experimental Student Worksheet using Vee Diagram framework, and Elementary School curriculum analysis for grades IV, V, and VI can be seen at Figure 4.

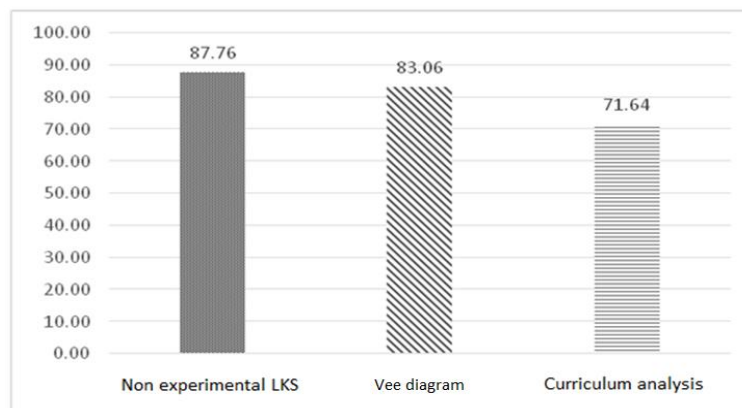


Figure 4. Average of the elementary school pre-service teacher students' mental efforts

The measurement result for the Pre-Service Teacher students' mental efforts in the almost the same courses. In the subject of Curriculum Analysis for the Pre-Service Teacher students' mental efforts seems increasing. The average value of the students' mental efforts can be seen on Figure 4. Sweller and Chandler [19] mentioned the easy material was not too burdening the working memory so that there is still a space to shape a new knowledge scheme. None of the Pre-Service Teacher on the first and second material stated that the lecture strategy is less helpful. On the third material, there is one Pre-Service Teacher students stated that lecturing is not helping him/her in understanding the material.

Based on Figure 1, the mental efforts on the Natural Science and Pedagogy contents integrated lecture in the subject of making non-experimental Student Worksheet, there are only two categories for the Pre-Service Teacher students' mental efforts namely very-low and low ones. This finding shows that the Pre-Service Teacher student doesn't have significant difficulties. The discussion of *Think Pair Share* helps the Pre-Service Teacher students to enhance his/her capability to formulate the productive questions as one of the Student Worksheet components. Using the orange picture helps the students to formulate the questions. Sweller [16] said that a picture was a representation to simplify in understanding the material. The same thing was also expressed by Mayer [20] whereas illustration was beneficial for those receiving education that had less early knowledge. Contrary to the statement, the lack of clarity for picture or illustration so that it was different from the object being observed can improve the Pre-Service Teacher students in processing the information.

The mental efforts burdened to the Pre-Service Teacher students with strategy as explained in the subject of making experimental Student Worksheet using Vee Diagram framework are obtained in two

categories mental efforts namely very-low and low ones. This finding shows that a developed and applied strategy is successful in helping the Pre-Service Teacher students in understanding the material with or without giving heavy burden to their working memory.

Morrienboer and Sweller [21], stated that the knowledge scheme contained in the long-term memory if it keeps using repeatedly can become an automation. A knowledge scheme that becomes automation can be processed unconsciously, and therefore can reduce the cognitive load. In the lecture with the subject of making experimental Student Worksheet using Vee Diagram framework, the assessment is implemented 3 times namely classically, in the group, and at the time of assignment. The assessment and finding processes regarding the Student Worksheet quality rumored at school, give knowledge and understanding for the students that the Student Worksheets spread give less the guaranty for good quality. The Student Worksheet trial test activity directly helps the Pre-Service Teacher students understand the concept being experimented. The activity for revising the Student Worksheet can help the Pre-Service Teacher students make the Student Worksheet good quality. Kalyuga [22], stated the lack of extraneous cognitive load (as described by the mental efforts) will give space for working memory to be used in making new knowledge scheme in the long term memory.

In the Elementary curriculum analysis for grades IV, V and VI, the mental efforts for the Pre-Service Teacher students are increasing. There is 12.9 % (Figure 3) of Pre-Service Teacher students who need bigger mental efforts (average mental effort). The increasing condition in this material can be caused by the lack of prior knowledge that the Pre-Service Teacher students have. Kalyuga [22] called it with inadequate prior knowledge situation. This situation constitutes a condition where the Pre-Service Teacher students do not have adequate early knowledge in order to process new information in his/her working memory, so that it causes the excessive load on his/her cognition. This situation can increase extraneous cognitive load. Lack of relevant early knowledge to process obtained information resulted the Pre-Service Teacher students in using other efforts apart from his/her cognitive capabilities [23]. It makes it possible to cause the mental efforts more increasing.

The material complexities can be one of the factors for the reduction of Pre-Service Teacher students' capabilities for analyzing information [19]. Compared to the previous materials, the curriculum analysis has the high material complexity. Morrienboer and Sweller [21] stated for the material that contained high interactivity element, the need for reducing extraneous cognitive load is necessary in order to give space at the working memory in shaping a knowledge scheme. Based on the statement, the eighth material contained high material complexity need to be considered to reduce mental efforts. Reducing mental effort can decrease the extraneous cognitive load so that it can give more space for the working memory and does not result cognitive overload.

4. Conclusion

The pedagogical content and knowledge of solar system course discloses the mental efforts for the Elementary School Pre-Service Teacher students in attending the solar system in Elementary School Natural Science Education lecture involving the material of making non-experimental Student Worksheet, making experimental Student Working using Vee Diagram framework, as well as the Elementary School curriculum analysis for grades IV, V and VI. According to the the data analysis result, it is found out that an applied lecturing strategy results in low mental efforts. The increasing mental efforts are shown in the curriculum analysis lecture resulted from the lecture material complexities.

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