Applying of teaching strategy based on cognitive load theory to develop pre-service teacher teaching skills of waves: Cognitive load analysis

To cite this article: I Permana et al 2019 J. Phys.: Conf. Ser. 1157 022026

View the article online for updates and enhancements.
Applying of teaching strategy based on cognitive load theory to develop pre-service teacher teaching skills of waves: Cognitive load analysis

I Permana¹,²,*, H Firman¹, S Redjeki¹, I Hamidah¹

¹ Program Studi Pendidikan IPA, Sekolah Pascasarjana, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung 40154, Indonesia
² Universitas Pakuan, Jl. Pakuan No.1, Bogor 16143, Indonesia

*irvanpermana@student.upi.edu

Abstract. This study aimed to reveal Pre-Service Teacher’s cognitive load representing the effectiveness of teaching strategy based on cognitive load theory. Cognitive load is described as correlation among Intrinsic Cognitive Load (ICL) and Extraneous Cognitive Load (ECL). Teaching strategy was developed by Cognitive load Theory with the stages such as Introduction, Reflection, Visualization, Application, Recitation, and Evaluation. Participants in the study were 31 pre-service science teachers in Bogor and Bandung Indonesia. Data of ECL were collected with a complexity task containing a short question to measure the ability of information analysis during lecturer. ECL data were collected with a 7-scale questionnaire contains a statement of the mental effort of pre-service science teachers in lecturer. Result of data analysis found that applied lecture strategy successfully improved pre-service science teachers ICL and reduce ECL. This strategy produced low mental effort especially at introduction stage. The mental effort increases on the application stage.

1. Introduction
In the Indonesian Curriculum 2013, science subjects in junior high school consist of integrated physics, chemistry and biology content in Basic Competency and integrated learning. Changes in the learning process in science require teachers to master science in the form of content mastery and science Pedagogical Content Knowledge (PCK). One of the main issues of pre-service science teachers in teaching Integrated Science is the skills of teaching still low. Integrated science teaching skills are influenced by conceptual integration related to the ability of pre-service science teachers in processing information received while studying the course material, either during lecturing process or when studying material from various sources and how to deliver materials [1].

The integrated science research that integrates content with pedagogy for pre-service science teachers successfully improves the readiness and skills of teaching pre-service science teachers to teach [2][3][4]. Science essentially includes the four main elements of attitude, process, product, and application. However, the provision of learning in accordance with the nature of the science has not been obtained during the lecture [4]. This causes the cognitive load of pre-service science teachers to be high at the time of learning integrated science materials [1]. To reduce the cognitive load, it is necessary to prepare the integrated science PCK on teaching skills for pre-service science teachers. Pre-service science teachers’ PCK is a necessary for their career as science teacher. With sufficient PCK, teacher should be teach a content in a reasonable way and prevent misconception.
Learning process is related to the ability of memory to receive information. Each person’s memory capability is different and has limited capacity so that it becomes a load when having to receive a lot of information. The load a person experiences in receiving information is explained in Cognitive Load Theory (CLT). CLT aims to predict and apply learning successfully and effectively supported by teaching and instruction [5]. The design of cognitive understanding will be effective and efficient if it has a working memory load stored within its capacity limits. Understanding of how cognitive processes work and working memory of pre-service science teachers are the basis to improve learning that is appropriate to the way students learn pre-service science [6] [7].

Three CLT principles in instructional design development according Meisner and Bogner [8]:

1. Using different approaches to align intrinsic cognitive load from complex tasks. Reducing the intrinsic cognitive load can be done by restructuring tasks starting from simpler and less complex material, developing relatively easy tasks, simplifying complex tasks and then continuing with more detailed explanations in stages.

2. Reducing ECL, such as:
   a. Reduce split attention effect. Split attention effects [9] occur when learners have to remember multiple information simultaneously: integrating mental information from multiple sources can increase the interactivity of elements in working memory. Split attention effect decreases when information is provided in condensed mode rather than separately (e.g. comment is integrated into picture).
   b. Reducing Redundancy effects. The Redundancy effect occurs when a task consists of a lot of information that does not need to be understood: Learners should invest in working memory capacity to process information overload, resulting in unnecessary elements of interaction [10]. This effect also includes the effect of expertise reversal [11] as learner prior knowledge and expertise that determines whether or not certain information is excessive. High-skilled learners can deal with more information than beginners. The problem-solving effect is very similar to a working example: If an assignment already provides a solution step (solution completion) or complete solution (workspace) framework, learners do not have to implement a very demanding way.
   c. Problem solving strategies

3. Increasing learner motivation to invest the working memory capacity for learning process. For this purpose, it takes a variety of tasks and appropriate scaffoldings. High task variability allows learners to become familiar with the conditions under which a particular method can be applied. Guidelines for self-explanation help guide learners’ thinking and help learners to know what they are doing if learners need to formulate the explanations they need to process information relevant to learning.

According to [12] and [13], debriefing for pre-service science teachers in Integrated Science teaching skills on wave materials and developing positive attitudes and perceptions to reduce cognitive load is essential. This study was to measure the relationship between Intrinsic Cognitive Load (ICL) and Extraneous Cognitive Load (ECL) on the skills of teaching pre-service science teachers. ICL measurements are performed on the basis of information processing and ECL is done through the mental effort of pre-service science teachers in developing teaching skills on wave materials.

2. Method

2.1. Participants
This research was followed by 31 participants from two universities. Participants were pre-service teacher of science in Bogor (3 male 16 female) and Bandung (12 female) Indonesia semester 7. All the participants age from 20-22 year.

2.2. Teaching strategy based on cognitive load theory
Teaching strategy based on CTL included 5 Stage Introduction, Reflection, Visualization, Application, Recitation, and Evaluation. In the introduction stage the lecturer explains the background of the importance of basic pedagogy and Integrated Sciences content for students. In reflection stage students
are invited to reflect themselves, identifying the gap between skills that he/she has with the demands of the curriculum. In Visualization stage student observe a simulations teaching science conducted by lecturer. The teaching simulation applies a scientific approach with local material (Figure 1).

![Figure 1. Using rope to demonstrate relationship among pulse and wave](image1)

When simulation lecturer using several methods, e.g demonstrations with rope for the concept of transversal waves, using ruler for pulse, and using multimedia for hearing mechanism (Figure 2).

![Figure 2. Multimedia in teaching simulation](image2)

At the application stage, collaboration method applied. Students identify teaching skills, contextual concepts, media types and questioning strategies based on teaching simulations. At recitation stage student Select basic competencies (KD) and analyze the content covering key ideas, teaching strategies, contextual content, and creating probing questions. The course ends with an evaluation stage.

2.3. Instruments

Intrinsic Cognitive Load (ICL) was measured with a complexity task containing a short question (5 items) to measure the ability of information analysis during a learning activity to take place. External Cognitive Load (ECL) is measured using a 7-point Rating Scale Mental Effort (RSME) by [14]. Categorization of ECL adapted from [15] shown in Table 1.

| Table 1. Mental Effort Category |
|---------------------------------|
| Point | Category         |
| 1     | absolutely no effort |
| 2     | almost no effort   |
| 3     | little effort      |
| 4     | some effort        |
| 5     | moderate effort    |
| 6     | great effort       |
| 7     | very great effort  |
2.4. Data analysis

Both instruments are given at the end of the lecture. The identification of ECL at each stage of the lecture is determined descriptively by analysis of the percentage of mental effort categories. To determine the relationship between ECL and ICL was analyzed by Pearson product moment correlation test using SPSS program.

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 Natural Science and Pedagogy contents integrated 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 Pedagogy and Natural Science contents integrated lectures.

3. Result and Discussion

3.1. The Intrinsic Cognitive Load (ICL)

Based on task complexity worksheet results student ICL students is shown in Table 2

| Component | Q1 (max 5) | Q2 (max 3) | Q3 (max 3) | Q4 (max 3) | Q5 (max 2) | Total Mean (conversion 100 point) |
|-----------|------------|------------|------------|------------|------------|----------------------------------|
| Mean      | 1.77       | 2.03       | 1.35       | 2.87       | 1.39       | 62.80                            |
| Std       | 0.76       | 0.71       | 0.49       | 0.34       | 0.56       | 9.55                             |
| Max score | 3.00       | 3.00       | 2.00       | 3.00       | 3.00       | 86.67                            |
| Min score | 1.00       | 1.00       | 1.00       | 1.00       | 1.00       | 46.67                            |

Based on Table 2 average of student ICL is 1.77 from the max score of 5 or 35.48%. It’s mean that the highest ICL is question 1 about teaching strategies. Students have obstacles to receive messages and process information about pedagogical materials through simulations by lecturer. The highest score of ICL is in question no 4 (2.87 of the max score or 95.70%). Question 4 asks for an example of a contextual plane concept to be answered very well by most students. Generally based on the mean total of students’ processing information ability is unsatisfactory (62.80).

3.2. The Extrinsic Cognitive Load (ECL)

According to [16] ECL could be defined with measuring mental effort. The results of ECL represent student mental effort to processing information in lecturer. The percentage of ECL at each stage of the lecture is shown in Figure 3.

At all stage of lecture the highest percentage of mental effort dominated by absolutely mental effort category. At Introduction stage, student with absolutely mental effort category dominates the class with 54.84%. Application stage is the most hard stage lecture. Based on Figure 2, student with some effort and little effort percentage is 3.23% and 18.28 respectively. At this stage, students do enough mental effort to understand the message through a teaching simulation. In general, the highest ECL at all stages of the lecture is in some effort category. The low level of mental effort shows the students can do the cognition process well. With the implemented IRVARE strategy, students can develop their teaching skills well.
3.3. Correlation between intrinsic cognitive load and extrinsic mental effort

The correlation between ECL and ICL was analyzed by Spearmen product moment correlation test shown in Table 3 and Table 4.

**Table 3. Normality of data**

| Variable | Biology |
|----------|---------|
| ICL      | sig. 0.11 Not normal |
| ECL      | sig. 0.17 Not normal |

Based on normality of data shown in Table 3, Spearmen correlation test was conducted to determine relationship between ICL and ECL. The results of the correlation test are shown in Table 4. According to Table 4 it found a negative and significant correlation between ICL and ECL with \( r (31) = -0.413, p <0.05 \).

**Table 4. Correlation and regression test result**

| Class  | Pearson test | Regression |
|--------|--------------|------------|
| ICL-ECL| 0.431*       | 0.021<0.05 | 0.115      | 11.5%      |

Data in Table 4 shows that ICL negatively correlated to ECL. This result indicates the teaching strategy based on CLT yield a level of ICL that could reduce the level of ECL because the negative correlation of ICL-ECL was significant (Table 4). ICL contributed to ECL 11.5% to reduce the mental effort in lecturer. IRVARE is a lecture strategy developed for pre-service science teachers in developing teaching skills on wave materials is effective with low ECL. This finding parallel with [17] that stated the purpose of instruction is to keep mental effort at a minimum during the learning process.

The purpose of the study was to identify pre-service science teachers’ cognitive load (ECL and ICL) when applying teaching strategy based on CLT. Finding of research contributes to the development of pre-service science teachers’ teaching skills with relatively low level cognitive load. However, students still have difficulty understanding concepts of science concepts. Findings of the study also shows that
at the application stage, students have some difficulties to understanding wave concept that simulated by lecturer. In this case, students meet split attention effect when they have to identity teaching skills and science content in same time.

4. Conclusion
The teaching strategy based on CLT that integrates content with pedagogy for pre-service science teachers successfully improve student ICL and reduce ECL. The lecture stage including Introduction, Reflection, Visualization, Application, Recitation, and Evaluation produced low mental effort especially at introduction stage. Visualization with teaching simulation by lecturer still yielded relatively low receiving and processing information about pedagogical knowledge.

Acknowledgments
This work was supported by Ministry of Research, Technology and Higher Education of Republic of Indonesia and additional support was gratefully provided by Universitas Pakuan Bogor Indonesia.

References
[1] Permana I Redjeki S Hamidah I and Safitri N, 2017 Pre-service Teacher Extraneous Cognitive Load in the Pedagogical Content and Knowledge of Solar System Course Pre-service Teacher Extraneous Cognitive Load in the Pedagogical Content and Knowledge of Solar System Course J. Phys. Conf. Ser. 895 p. 1–8.
[2] Nilsson P and Loughran J, 2012 Exploring the Development of Pre-Service Science Elementary Teachers’ Pedagogical Content Knowledge J. Sci. Teach. Educ. 23 p. 699–721.
[3] Wilson R E Bradbury L U and McGlasson M A, 2015 Integrating Service-Learning Pedagogy for Preservice Elementary Teachers’ Science Identity Development J. Sci. Teach. Educ. 26 p. 319–340.
[4] Bravo M A Mosqueda E Stoddart T and Solís J L, 2014 Possibilities and Limits of Integrating Science and Diversity Education in Preservice Elementary Teacher Preparation J. Sci. Teach. Educ. 25 p. 601–619.
[5] Plass J L Moreno R and Brunken R, 2010 Cognitive Load Theory Cambridge: University Press.
[6] Ong C P and Tasir Z, 2015 Self-instructional module based on cognitive load theory: A study on information retention among trainee teachers Educ. Technol. Res. Dev. 63, 4 p. 499–515.
[7] Yung H I and Paas F, 2015 Effects of Cueing by a Pedagogical Agent in an Instructional Animation: A Cognitive Load Approach Educ. Technol. Soc. 18 p. 153–160.
[8] Meissner, B and Bogner, F. X. 2013. Towards cognitive load theory as guideline for instructional design in science education. World of Journal Education, 3 (2), p. 24-37
[9] Sweller, J Chandler, P Tierney, P and Cooper, M. 1990. Cognitive load as a factor in the structuring of technical material. Journal of Experimental Psychology: General, 119 (2), 176-192.
[10] Chandler, P and Sweller, J. 1991 Cognitive Load Theory and the Format of Instruction. Cognition & Instruction, 8. p. 293-240.
[11] Kalyuga Ayres Chandler and Sweller. 2003. The Expertise Reversal Effect, Educational Psychologist, 38 (1), p. 23-31.
[12] Sweller, J. 2005. Implications of cognitive load theory for multimedia learning New York, Cambridge University Press.
[13] Mayer R E Heiser J and Lonn S, 2001 Cognitive constraints on multimedia learning: when presenting more material results in less understanding J. Educ. Psychol. 93 p. 187–198.
[14] Krell Moritz 2014 Evaluating an instrument to measure mental load and mental effort using Item Response Theory Science Education Review Letters 2015 p. 1-6
[15] Widyanti A Johnson A and de Ward D, 2013 Adaptation of the Rating Scale Mental Effort (RSME) for use in Indonesia International Journal of Industrial Ergonomics 43 p. 70-76
[16] Hindriana A F and Rahmat A, 2014 Beban Kognitif Mahasiswa Dalam Pembelajaran Fungsi Terintegrasi Struktur Tumbuhan Berbasis Dimensi Belajar Jurnal Ilmu Pendidikan 1 (20) p.
[17] Moreno and Park 2010 Cognitive Load Theory: Historical Development and Relation to Other Theories, in Plass J. L, and Brunken R (eds) Cognitive Load Theory Cambridge: Cambridge University Press p. 9-28