Students' extraneous cognitive load in cell biology lectures

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Abstract

This study aims to analyse students' extraneous cognitive load (ECL) in cell biology lectures. Participants in the study were 31 students of the Biology Education Department who attended the Cell Biology course from a university in Jakarta, Indonesia. The Cell Biology lectures include fours topics. The data of ECL were measured using questionnaires with a semantically differential scale, containing statements about students' mental efforts in understanding the information received in the lectures. The data obtained were then tabulated, categorised according to the mental effort rubric, and made into percentage for each step of the VARK (Visual, Aural, Read/write, Kinaesthetic) approach. The results of the data analysis show that students' mental effort (ECL) in understanding each concept in Cell Biology lectures through the VARK approach is generally in the lower category. This is indicated by the very high percentage in the low category for visual, aural, read/write, and kinaesthetic steps.

Keywords: Extraneous cognitive load, cell biology, VARK;

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1. Introduction

1.1 Theoretical basis and conceptual framework

Cognitive Load Theory (CLT) presumed that cognitive architecture consists of long-term memory (LTM) and working memory (WM) (Sweller & Sweller, 2006). Learners must process instructional information in the working memory (Sweller, Ayres & Kalyuga, 2011). The processing of new information is highly limited because new information has to be processed according to the *narrow-limits-of-change principle* prior to being deposited in LTM and then processed in WM. WM is severely restricted in both capability and length, unlike LTM (Paas & Van Merrienboer, 2020). Cognitive load theory was introduced by Sweller (1988), which distinguishes between three types of cognitive load, namely intrinsic cognitive load (ICL), extraneous cognitive load (ECL), and germane cognitive load (GCL). ICL is imposed by the nature of what is to be learned, including the number of information elements and their interactivity, while ECL is generated by how information is presented to learners. GCL refers to a load intended for processing or understanding a task (Sweller, 1988).

The main objective of the CLT is to improve the learning of complex cognitive tasks by translating contemporary scientific expertise into instructional design guidance on how cognitive frameworks and processes are structured (i.e., cognitive architecture) (Paas & Van Merrienboer, 2020). In order to construct schemas in long-term memory, novel data must be processed in working memory. An emphasis of CLT is the ease with which data in working memory can be processed. The WM load can be influenced either by the inherent nature of the learning tasks themselves (intrinsic cognitive load) or by the way tasks are carried out (extraneous cognitive load) (Van Merrienboer & Sweller, 2005).

Task-related aspects (e.g., instructional design), the learner aspects (e.g., intrusive ideas about failure), and the learning environment aspects may trigger ECL (e.g., distracting information in a classroom) (Paas & Van Merrienboer, 2020). Since working memory has limitations, instructional designs must be set up to reduce all types of cognitive load (Ong & Tasir, 2015). In his theory, Sweller (1988) suggested that the way in which information is presented can affect its load, and as a result, it influences whether someone can maintain information or he will be overloaded and cannot maintain it. The research findings of Sweller suggest that ECL should be an important consideration when designing the learning process. ECL, by definition, is completely under instructional or learning control (Ong & Tasir, 2015). Learning activities should be structured in such a way that the WM ability available is effectively exploited to achieve the maximum return on investment in mental effort. This implies that ECL should be reduced in order to release WM power, which may allow the operating resources allocated to intrinsic cognitive load to be increased (also called germane processing) (Paas & Van Merrienboer, 2020).

1.2 Related studies

Several previous studies on cognitive load have been conducted such as research on nine ways to reduce cognitive load in multimedia learning (Mayer & Moreno, 2003). In addition, there is also a study arguing that cognitive load can be reduced through integrated learning (Haslam & Hamilton, 2010) and that the use of learning strategies based on learning dimensions has reduced the cognitive load of students (Rahmat & Hindriana, 2014). There is also a related study on the mental efforts of students outside the school laboratory (Scharfenberg & Bogner, 2010). Another research found that the growing mental effort is due to the material complexities of the lecture (Permana, Redjeki, Hamidah & Safitri, 2017). In our previous studies, students' cognitive load in cell biology lectures was measured, which was

carried out by direct learning through a conceptual approach. The results of these studies indicate that ECL students are in the high category (Juanengsih, Rahmat, Wulan & Rahman, 2018a) Based on the results of these measurements, it is recommended that there must be an attempt to enhance the process of learning an effort to improve the learning process in cell biology lectures. The most recent ECL research was conducted by Miller, Stenmark & Ittersum (2020), who found that ECL can be reduced by several information displays.

1.3 Purpose of the present study

In this study, the learning approach used in cell biology lectures is the VARK approach. The VARK approach was first introduced by Fleming (2012), in which learning activities are developed according to four main sensory modalities. The four modalities are visual (V), aural/audio (A), read/write (R), and kinaesthetic (K). The VARK approach is chosen as a way to facilitate multimodal student learning styles. Based on the previous research, it is known that 60% of the study population is considered multimodal. This means that they show a preference for some learning methods. The multimodal learning environment allows instructional elements to be presented in more than one sensory modes, namely visual, aural, written, and simulation (Renuga & Vijayalakshmi, 2013).

In the Cell Biology lectures, each activity is designed to follow the VARK steps. In the visual step, students observe two-dimensional images, three-dimensional pictures, and video animation. For the aural/audio step, students listen to lecturers' explanations about the material being discussed. For the read/write step, students work on the material worksheets using various sources. For the Kinaesthetic step, students carry out simulation activities related to the discussed material. The details of the steps of the VARK learning on the structure and function of cell membranes are available from previous research (Juanengsih, Rahmat, Wulan & Rahman, 2018b).

This study focuses on measuring one of the cognitive load types (ECL) caused by the learning design in cell biology lectures using the VARK learning steps. The research objectives were to measure students' mental effort in understanding the four topics of cell biology and measure the mental effort for each step of the VARK approach.

2. Method

2.1. Research model

The one-group posttest-only quasi-experimental design. Treatment (quasy-independent variable), student received four topics of cell biology. Measurement (dependent variable), measure student ECL.

2.2. Participants
The participants in this research were biology education students from one of the universities in Jakarta city of Indonesia, studying in the third semester of 2018/2019 the academic year. In total, there were 31 students (age 19-20).

2.3. Data collection tools

ECL can be measured by measuring students' mental effort while studying. Mental effort is a second type of cognitive load, referring to the cognitive ability that the student actually allocates to manage the resource demands imposed by the task, which can thus be viewed as representing the real cognitive load (Paas, Ayres & Pachman, 2008). The data of ECL is measured using the questionnaire. The

questionnaire is in the form of a semantically differential scale varying from "very very easy" to "very very difficult" (Brunken, Seufert & Paas, 2010) which is shown in Table 2. The subjective rating scale used a 1 to 9 scale, containing statements about students' mental efforts in understanding the information received in the lectures. Example of statements on the questionnaire is such as "after observing 2D images and animated videos of the types of receptors on the membrane, you are asked to identify the type of receptor on the membrane". Afterwards, the students rate their mental effort by selecting a scale of 1 to 9.

The subjective rating scale used has indicators that correspond to indicators for each topic of cell biology lectures. Each statement was divided according to the steps of the VARK learning, namely the Visual (V), Aural/Auditory (A), Read/Write (R), and Kinesthetic (K) steps. The statements indicate the strategies used to receive information for each concept in which students are asked to rate their mental effort perceived subjectively. For a complete number of statements for each topic in each step, see Table 1. Testing the content validity of the instrument in this study was carried out using expert judgment. Instrument testing was carried out on 31 students, then the validity and reliability were measured by Cronbach's alpha. The instrument's validity shows a value between 0.356-0.821 (r table = 0.355), which indicates a valid tool. Reliability for the four tools showed a value of 0.747-0.767, which in the high category.

Table 1. The number of questions for each topic for each step of the cell biology lecture by VARK

Topics	Visual (V)	Aural/Auditory (A)	Read/Write (R)	Kinaesthetic (K)	Total
structure and function of the cell membranes	16	5	1	4	26
nucleus-ribosomes-protein synthesis	9	8	5	2	24
cell cycles	4	5	5	2	16
cell communication	11	6	5	3	25

2.4. Analysis of data

The score to show students' mental effort uses a 9-point scale (Table 2), then the mental effort scores obtained were categorised into 5 categories: very high, high, average, low, very low (Table 3) as an adaptation of the categorisation by Arikunto (2010). The data obtained from the subjective rating scale are then tabulated, categorised according to the mental effort rubric and made into percentage.

Table 2. Mental effort instrumental scoring rubric

Score	Category
9	Very very difficult
8	Very difficult
7	Difficult
6	Rather difficult
5	Neither easy nor difficult
4	Rather easy
3	Easy
2	Very easy
1	Very very easy

Table 3. Mental effort categorisation

Score	Conversion scale 100	Qualitative category
7.40 < x ≤ 9.00	80 < x ≤ 100	Very High
5.80 < x ≤ 7.40	60 < x ≤ 80	High
4.20 < x ≤ 5.80	40 < x ≤ 60	Average
2.60 < x ≤ 4.20	20 < x ≤ 40	Low
1.00 < x ≤ 2.60	0 < x ≤ 20	Very Low

3. Results and discussion

Based on the results of the questionnaire given to the students of the Biology Education Department who have taken cell biology lectures using the VARK approach, it is found that mental effort in the low category is more dominant than the other mental effort categories. The percentage of mental effort on the first topic, namely the structure and function of the cell membrane, is shown in Figure 1.
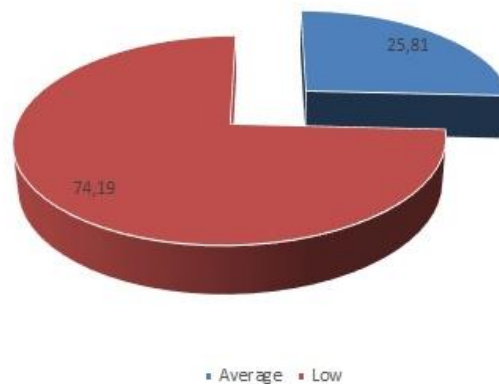

Figure 1. Diagram of the mental efforts of the biology education students on the topic of structure and function of the cell membrane

Figure 1 shows the mental efforts of students on the structure and function of the cell membrane which is divided into two categories, namely the low category at 74.19% and the very low category at25.81%. The percentage of mental effort on the second topic (nucleus-ribosome-protein synthesis) is shown in Figure 2.
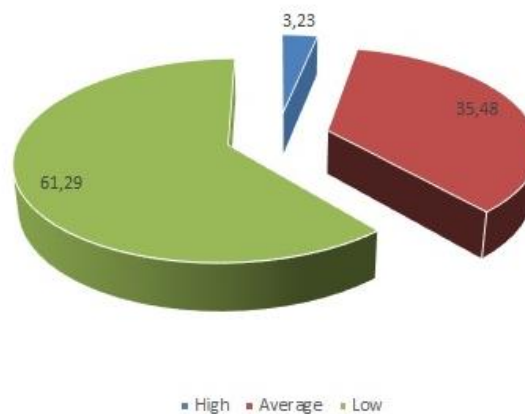

Figure 2. Diagram of the mental efforts of the biology education students on the topic of nucleus-ribosome-protein synthesis

Figure 2 shows the mental effort of students on the topic of nucleus-ribosome-protein synthesis which was divided into three categories, namely the low category at 61.29%, the average category at 35.48% and the high category at 3.23%. The percentage of mental effort on the third topic -the cell cycle- is shown in Figure 3.
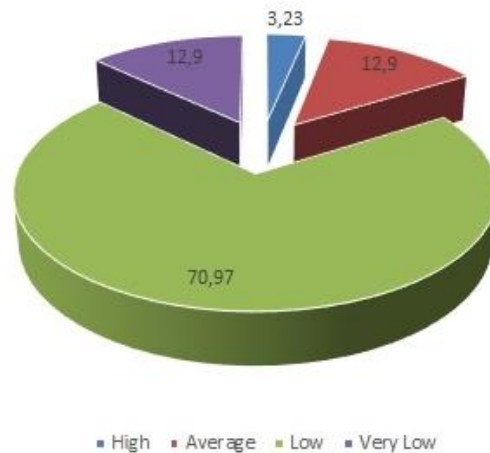

Figure 3. Diagram of the mental efforts of the biology education students on the topic of the cell cycle

Figure 3 shows the mental effort of students on the topic of the cell cycle which is divided into four categories, namely the very low category at 12.9%, the low category at 70.97%, the average category at 12.9% and the high category at 12.9%. The percentage of mental effort on the fourth topic, namely cell communication, is shown in Figure 4.
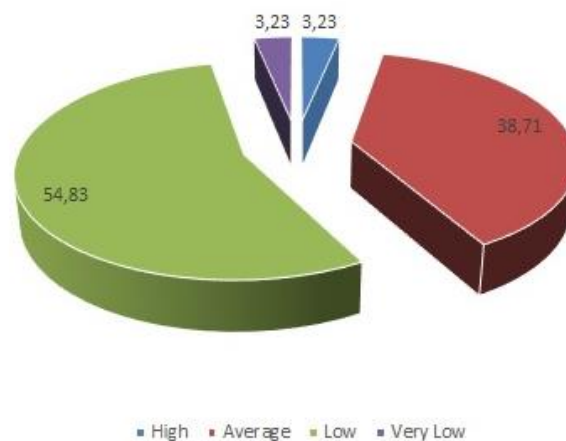

Figure 4. Diagram of the mental efforts of biology education students on the topic of cell communication

Figure 4 shows the mental efforts of students on the topic of cell communication which are divided into four categories, namely the very low category at 3.23%, the low category at 54.83%, the average category at 38.71%, and the high category at 3.23%.

Based on information from the above figures, it is known that the topic of cell membrane structure and its function is part of the lecture materials that is easier for students to learn than the other three topics. This is indicated by the emergence of only two categories of student mental effort, namely very low and low categories. This is in line with what was expressed by Sweller and Chandler (1994) that is the easy material does not burden working memory so that there is still space to form new knowledge schemes. As for the second topic, there are three categories of mental effort, while in the third and fourth topics there are four categories of mental effort. This shows that the third and fourth materials are more complex than the first and second topics. The mental efforts of students at each step of the VARK learning for each topic are shown in Figure 5.
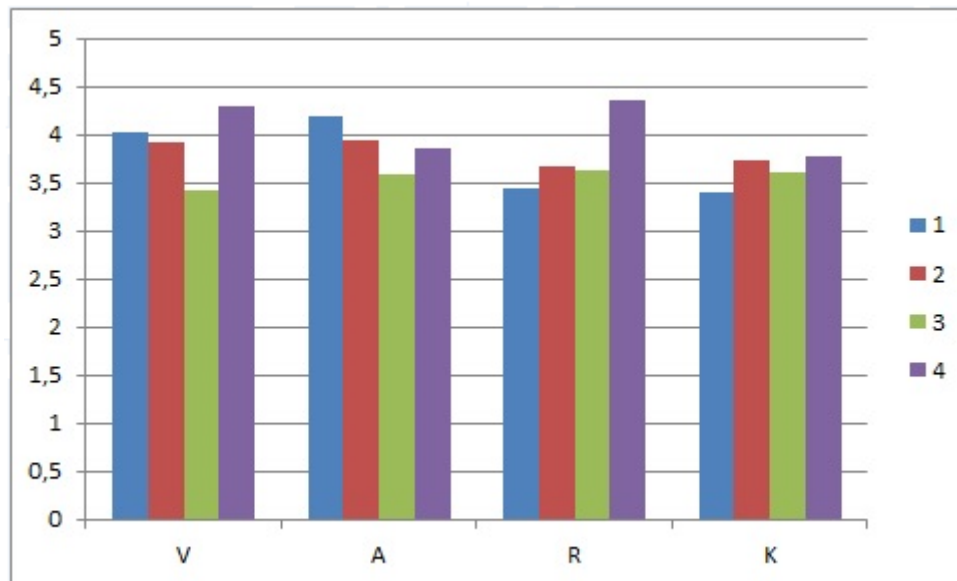

Figure 5. The mental efforts of students at each step of the VARK learning in Cell Biology Lectures

Based on Figure 5, it can be seen that at the visual and aural steps of the VARK learning, the lowest mental effort for students is on the third topic, the cell cycle. This shows that for the topic of the cell cycle, learning strategies using various 2-dimensional and 3-dimensional images and animation at the visual step of the VARK learning are more effective, as well as the lecturer's strategy of explaining the topics discussed so that students can listen well. This proves that the image representation can serve to make it easier to understand the material as suggested by Sweller (2005). These findings are in line with the research of Mousavi, Low & Sweller (1995) that effective working memory can be improved by presenting material in mixed modes rather than a single mode. These findings also show that for the topic of the cell cycle the visual step is better than the aural step, this is by the results of the research of Klingner, Tversky & Hanrahan (2011) that the cognitive load is lower for visual than aural presentation.

In the read/write and kinaesthetic steps of the VARK learning, the lowest mental effort for students is on the first topic, namely the structure and function of cell membranes. This shows that the topic of structure and function of cell membranes is easier for students to learn by reading, writing, and conducting experiments and simulations.

In Figure 5, another research finding is that the kinesthetic is the step of the VARK learning which requires the lowest mental effort compared to all the learning steps. This is consistent with Edgard Dale's cone of learning experiences that students will remember more than 90% of what they do directly (Davis & Summers, 2015). In the cell biology lecture for the first topic, students carry out simple experimental activities and for the second, third, and fourth topic students carry out simulations related to the concepts being studied.

In figure 5, it can also be seen that the highest student mental effort is in the concept of cell communication at each step of VARK learning. This is an indicator that the concept of communication is a topic that has the highest complexity compared to other topics, as task complexity ratings may also be an indicator of the material's intrinsic load (Brunken et al., 2010). Van Merrienboer and Sweller (2005) state that for complex material, a new method is needed to reduce cognitive load. It also illustrates that the magnitude of the ECL is intrinsically determined by the degree to which task-irrelevant data is fundamental to the core sense of the information to be learned (Miller, Hazan-Liran & Cohen, 2019). Another source of ECL may be from learners who may concentrate on other learning aspects (Fraser et al., 2018). This finding implies that there is a need for educators to simplify the concept of cell communication and to find appropriate learning methods or strategies to convey the concept so that students can understand this concept better.

4. Conclusion

Based on the results of the questionnaire given to the Biology Education students who had taken the Cell Biology course with the VARK approach, it is known that mental effort on all topics is dominated by the low category compared to the other categories. This showed that learning with the VARK approach can reduce student ECL.

The lowest mental effort for students is on the third topic, the cell cycle. The highest student mental effort is in the concept of cell communication at each step of the VARK learning. Growing mental efforts are seen in the concept of cell communication resulting from the complexities of the lecture content.

5. Recomendation

This study recommends that cell biology lecturers apply the VARK approach to facilitate student learning style preferences. Thus, it can reduce student extraneous cognitive load. Regarding cell communication material, strategies need to be considered to simplify the concept further so that the method can reduce the material's complexity.

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