The relation of student’s diagram comprehension, knowledge and cognitive activities while studying mosses metagenesis diagram

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Abstract. The students’ success in understanding the visual representation such as diagram, can be determined by cognitive activities that occurs in working memory. One of the diagrams that are abstract and difficult to understand while studying Biological material is plant metagenesis diagram. The aim of the study is to reveal the types of cognitive activities that relate to knowledge and diagram comprehension while students read mosses metagenesis diagram. Twenty five Biology education students completed mosses metagenesis knowledge test and diagram comprehension test (m = 48.9). Verbal data were collected by Think Aloud Protocol to find several types of cognitive activities while students read mosses metagenesis diagram. Four types of cognitive activities that found and correlated strongly with diagram comprehension, were 1) identifying of image detail (r = 0.917; p <0.01), 2) symbols interpretation (r = 0.862; p <0.01), 3 ) activating prior knowledge (r = 0.703; p <0.01), and 4) inference (r = 0.773; p <0.01). These results indicate the high frequency of identifying image detail, symbols interpretation, activation prior knowledge, and inference contributing to the high understanding of mosses metagenesis diagram. This study also reveals that students’ knowledge has contributed highly to students’ diagrams comprehension.

1. Introduction
Learning media such as book contains a lot of visual representations. Kind of visual representation which contained in book are pictures, photographs, diagrams, texts, graphics, tables, equations, and maps. Visual representations have an important role in the learning process and its serves as the carrier of ‘meaning’ [1]. The studies reveal that the students fail to understand visual representations in their learning resources [2,3,4]. Students' success in understanding visual representation to construct mental representation are determined by several factors including cognitive activity and complexity of diagrams [2]. Cognitive activities are important, they have a major role in constructing students’ understanding while studying
diagram [5]. Cognitive activities can only be obtained through observation of students' verbal reports using think aloud protocol [6,7].

In the 1960s and 1970s Jan Elshout and his colleagues held a study of cognitive skills related to generic intelligence using a method of verbal reports collecting. Verbal reports are converted to data through coding process. The coding method through verbal reports is called think aloud method [8]. The think aloud method is composed by an instruction that asks someone to think-aloud about how to solve problems and analyses of the verbal protocols from the resulting answers. Verbalization is the final stage of the process of information processing that occurs in working memory. The information processing process consists of perception, retrieval, construction, storage, and verbalization [8]. Think aloud method is applied in psychological and cognitive processes research. The instrument of think aloud method is known as Think aloud protocol [8]. In addition, think aloud protocol can be used to find learning activities that occur in working memory [2,6,7,9]. Learning activity that occur in working memory and appears when a person reads diagram is cognitive activity [6]. Comparative studies of students' cognitive activity while learning text and diagrams have been conducted by several researchers. Cognitive activities that appear when students read the diagram are activation of prior knowledge, relate the prior knowledge, inferences, alternates hypotheses, compares, summarizes, paraphrases and understand convention features [2,3,4,9].

The research related to cognitive activity in Biology learning is rare, whereas many diagrams are difficult to understand when students learn Biology matters. The diagrams that are abstract and difficult to understand are the process of protein synthesis, photosynthesis, and complex cycles [3]. One of the complex cycle diagrams that must be understood by students is plant metagenesis. The aims of this research are to reveal the type of cognitive activities that appears while students learn or read mosses metagenesis diagram and to find the relationship of these cognitive activities, knowledge and diagram comprehension.

2. Method
Descriptive research method used in this research. The subjects or participants in this research are Biology education department' students of Universitas Pendidikan Indonesia who are still actively attending the course. The subjects were chosen through convenience sampling technique and data collection held after course activity was done. Students' mosses metagenesis knowledge was collected through written test before they studied mosses metagenesis diagram. Students' cognitive activities while studying mosses metagenesis diagram obtained by using Protocol Think Aloud. This protocol is composed of two components, 1) instructions that ask students to verbalize what they think and 2) analysis of verbal reports of the answers generated [8]. The analysis of verbal reports consists of coding or grouping the types of cognitive activities that appear to be true and counting the frequency of similar verbal reports. The result of verbal report analysis is data of cognitive activities that appear while students studied the mosses metagenesis diagram [8]. After the students studied the diagram, they were asked to answer the comprehension diagram test orally. So that the data of diagram comprehension were obtained. Finally, Pearson and Spearman correlation was used to analyses the data that have been collected.

3. Result and discussion
Table 1. presents the frequency (person) of the student based on the mosses metagenesis knowledge category. The results in Table 1. were obtained from mosses metagenesis knowledge test before students studied the diagram. Base on the table 3.2, it was found that, 19 of 25 students had low mosses metagenesis knowledge category. 4 of 25 students had medium category and 2 other students had high mosses metagenesis knowledge category. This result proves that only 8% of students who have high
mosses metagenesis knowledge category and 76% of students have low knowledge mosses metagenesis knowledge category.

**Table 1.** Student’ frequency (person) base on mosses knowledge categories.

| Mosses metagenesis knowledge score | Knowledge categories | frequency (person) |
|-----------------------------------|----------------------|--------------------|
| 25 – 44                           | Very low             | 9                  |
| 45 – 59                           | Low                  | 10                 |
| 60 – 74                           | Medium               | 4                  |
| 75 – 89                           | High                 | 1                  |
| 90 – 104                          | Very high            | 1                  |

Based on verbal reports through think aloud protocol, four types of cognitive activities appeared while students read the mosses metagenesis diagram. The four types of cognitive activity were activating prior knowledge (K1), identifying of image detail (K2), symbols interpretation (K7) and inference (K8). This finding is different from the findings presented by Kragten (2015), in his research. Kragten found four cognitive activities that appeared while students read the metabolim process diagram, the cognitive activities that appears are activating prior knowledge, symbols interpretation, comparing and make alternative hypothesis [6]. The differences of cognitive activity that appear while students read diagram, can be influenced by different characters and content of that diagram. Based on these findings, researchers assume that different types of diagrams and diagram content will affect the types of cognitive activity that appear.

**Table 2.** Kind of Cognitive Activities base on student’s verbal report.

| Kind of cognitive activities (Code) | Definition                                                                 | Student’ Verbal Report                                                                 | \(f(\%)\) | \(M\) |
|------------------------------------|---------------------------------------------------------------------------|----------------------------------------------------------------------------------------|----------|-------|
| Activating prior knowledge (K1)    | Students recall relevant prior knowledge from long-term memory while reading mosses metagenesis diagrams | • So this picture shows the metagenesis of mosses (Riska) / Bryophyta (Ryan) / Musci (Alfi)  
• Bryophyta is one of the thallophyta that has metagenesis phase. (Zaitun)  
• Meiosis division converts diploid chromosome into haploid (Achmad)  
• Sporangium is a part of plant where spores are produced (Afini)  
• The sperm and ovum cells are gamete (Hamidah)  
• Pseudo-leaves and pseudo-roots are called thalus, because the roots, stems and leaves are not yet recognizable (Hamidah)  
• Mosses’ spores will produce protonema (Via), fern’ spores will produce protalium (Alifah) | 80          | 3.35  |
| Identifying image detail (K2)      | The student identifies and mentions each detail of the picture in sequence | • sporocytes take on meiotic division (1), its produce haploid spores (2), haploid spores develop into protonema (3), ... etc.  
• Anteridium is a reproduction organ of males (1), Arkemonium is a female reproductive organ (2). Arkansas will produce ovum (3) and anteridium will produce sperm (4) ... when sperm and ovum cells start to fertilization, its will be produce zygot (5) ... etc | 100       | 12.70 |
| Symbol interpretation (K7)          | Students reveal the meaning of a symbol, color, or arrow                  | • This green color shows the sporophyte phase and black color indicates the gametophyte phase (Rizka)  
• Gamete cells take on mitosis division, to keep their chromosome number haploid (pointing red arrows and colored core images) (Ahmad) | 80        | 4.65  |
| Inference (K8)                     | Verbalize an inference of the diagram that students see                   | • The fertilization process produce zygote and it will develop into sporophyte to produce spores, sporophyte produce gametophyte body and gamete cell, and then fertilization, then the process of fertilization and metagenesis always repeated (Syauqi)  
• Fertilization process of sperm and ovum cells will produce a zygote and the mosses metagenesis cycle will recur (Naufal) | 48        | 0.92  |

Table 2. presents the cognitive activities with sample verbal reports presented by students while reading mosses metagenesis diagram. Based on table 2. it can be seen that each student shows the activity of
identifying image detail with the average appearance (M) 12.7 times while reading mosses metagenesis diagram. Around 80% of students show the activity of activating prior knowledge and symbol interpretation. Around 20% of students remain did not shows the activity while reading the diagram. Furthermore, there are only 48% of students who did inference activity with average appearance (M) 0.92 times at the time while they read mosses metagenesis diagram.

In addition, other findings in this study can be seen in table 3. The analysis of students diagram comprehension shows that 28 % of students have high mosses metagenesis diagram comprehension category. As much as 36 % of students have medium diagram comprehension category and 36 % of students remain have low mosses metagenesis diagram comprehension category.

Table 3. Student’ frequency (person) base on mosses diagram comprehension categories.

| Mosses diagram comprehension score | Diagram comprehension categories | Frequency (person) |
|-----------------------------------|---------------------------------|-------------------|
| 9.5 – 26                          | Very low                        | 4                 |
| 26.5 – 43                         | Low                             | 5                 |
| 43.5 – 60                         | Medium                          | 9                 |
| 60.5 – 77                         | High                            | 5                 |
| 77.5 – 94                         | Very high                       | 2                 |

Correlation analysis is operated to reveal the relationship between students’ mosses metagenesis knowledge, frequency of cognitive activities and diagram comprehension. Correlation analysis result are present in table 4. Strong correlation formed between diagram comprehension score and metagenesis knowledge score, diagram comprehension score and all of cognitive activities. Furthermore, Another strong positive-value correlation is also formed between the diagram comprehension score with 1) identifying of image detail (r = 0.917; p <0.01), 2) symbols interpretation (r = 0.862; p <0.01), 3 ) activating prior knowledge (r = 0.703; p <0.01), and 4) inference (r = 0.773; p <0.01).

Table 4. Correlation matrix of students’ diagram comprehension, knowledge and cognitive activities.

| Kognitive activities (Code) | K1 | K2 | K7 | DC | MK |
|-----------------------------|----|----|----|----|----|
| K1                          | 0.432** | 0.491* | 0.703** | 0.580** |
| K2                          | 0.432** | 0.716** | 0.917** | 0.644** |
| K7                          | 0.491* | 0.716** | 0.862** | 0.488** |
| DC                          | 0.703** | 0.917** | 0.862** | 0.690** |
| MK                          | 0.580** | 0.644** | 0.488** | 0.690** |

DC, diagram comprehension
MK, mosses metagenesis knowledge

Based on the findings above, it can be said that person's cognitive activities derived from verbal reports and verbalization of person depends on the process of information processing that occurred before [8]. Before a person start to verbalize, in the retrieval stage, the relevan prior knowledge on the long term memory is retrieved and activated in the working memory domain. However, this occurrence will not occur if a person does not have relevant prior knowledge in long term memory [8]. This is the reason why students who have low mosses metagenesis knowledge will be silent or will not give any verbalization while reading mosses diagram. Researchers assumed that high frequency of cognitive activities will be appeared when a person has high relevant prior knowledge in long term memory.
The low presentace or low average frequency of students’ inference was closely related to low mosses metagenesis knowledge and another cognitive activities such as activating prior knowledge and symbols interpretation. The findings of this study are consistent with the findings of Griffard [10] stating that students' success in interpreting diagrams is influenced by several other cognitive activities such as identifying missing information, recalling prior knowledge (activating prior knowledge), and noticing features graphics (such as interpreting symbols) [10]. In this study, students who successfully understand the diagram, performing 4 cognitive activity with a relatively high frequency of occurrence in each category. These findings indicate that high prior knowledge and frequency of activating prior knowledge (K1), identifying of image detail (K2), symbols interpretation (K7) and inference (K8) are contribute to the high mosses metagenesis diagrams comprehension.

4. Conclusion
Mosses metagenesis knowledge of Biology education’ students before studied mosses metagenesis diagram consists of 5 categories that are very low, low, medium, high and very high. More than 50% of student have low mosses metagenesis knowledge category and 28% of students have high mosses metegensis diagram comprehension category. The cognitive activities that appear while students studied mosses metagenesis diagram and strongly related to the diagram comprehension are activating prior knowledge (K1), identifying of image detail (K2), symbols interpretation (K7) and inference (K8). High frequency of activities identifying of image detail, symbols interpretation, activating prior knowledge, and inferencing, contributes to high mosses metagenesis diagrams comprehension. In addition, the students’ knowledge highly contributes to student diagrams comprehension.

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