Exploring undergraduate students mental representation and its correlation with information processing and their knowledge in learning plant transport using diagram convention

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Abstract. Application of diagram convention in learning helps students to understand biological concepts. This diagram is integrated in formation of facts of a concept. The aim of this study was to analyze the correlation between mental representation (MR) of undergraduate students when reading diagram convention with information processing and their knowledge. The 27 participants consist of undergraduate students of biology education in Bandung who are studying plant transport. MR data in form of causal network is obtained through worksheet instrument developed based on CNET protocol while information processing and knowledge through an essay instrument. There's a strong correlation between MR with information processing \((r = 0.578; p < 0.05)\) and MR with knowledge \((r = 0.679; p < 0.05)\). This result indicates that to represent a diagram being studied requires knowledge as a bridge to connect the information contained in the diagram. Important information in diagram is processed in working memory to form causal interactions between information elements and emerge in form of causal network. Two MR patterns are found namely linear (Markov chain) and simple branching (feedback control with a single measurement). Differences in MR patterns indicate the ability of students understand the information contained in the diagram.

1. Introduction

Biology is one of the subjects that have some abstract concept, where the abstract concept is difficult enough described and imagined by students so that there are still many students feel difficult to understand it [1]. One way that can help students in learning to construct knowledge by using diagram. Diagram is used in learning biology can facilitate cognitive process easier [2]. There is one way that diagram represents, namely through the use of diagram convention [3]. Within the diagram convention, an object is illustrated through the colors, symbols, icons, or the notation of certain meanings that describe the structure and its relationship with related functions of the structure.

The quality of construction of knowledge a person relies on mental representation (MR) that has been generated during the learning process [4]. Mental representation is an internal representation related to the representation of knowledge in cognitive systems that is formed through the interaction with visual or verbal information or object [5]. Formation of mental representation based upon causal interactions between the information elements. Causal interactions between the information elements seen on the basis of causal networks and show certain patterns might be different on each individual
Previous research revealed each individual has different qualities and patterns of mental representation. The differences appear when the students selected and sorted information elements that affects the formation of causal network [7].

Mental representation involves the information processing related to a particular object that is actively done in human cognitive system. The human cognitive system itself consists of working memory and long-term memory. Information processing involves the role of working memory, consist of four standards including information identification, information interpretation, relevance of information, and information application. When a person process new information in working memory, he/she will use prior knowledge that is called from long-term memory [8]. Prior knowledge owned by the students is an important factor in information processing. it is also able to reduce cognitive load because prior knowledge can accommodate the formation of good mental representation [9]. Novel knowledge that is formed will be stored in the form of schemes in long-term memory and can be represented again if the information is required [10].

Purpose of this research was to analyze the correlation of undergraduate students’ mental representation with information processing and their knowledge and also analyze patterns of mental representation that is formed when reading the diagram convention of transport plant. By knowing the correlation between mental representation with information processing, teachers are expected to determine a suitable visual media used in learning so that students are able to process information well and have a good mental representation. The MR pattern that is formed describes the construction of knowledge carried out by students during instruction. So that MR patterns that emerge from every student can become important information for teachers to determine which pattern is good for students to have it and as a reference in designing learning properly.

2. Method
This research is descriptive research. Participants in this study consist of 27 undergraduate students of Biology Education from one of private university in Bandung. Mental representation is measured based on causal network formed through CNET protocol instrument and information processing and knowledge measured through test instrument in the form of essay question. CNET protocol instrument contains a diagram convention of plant transport that include (1) the selecting and ordering of information elements; (2) determine the appropriateness of the order of information elements; (3) determination of the probability parameters by describing the relationships between information elements; and (4) determination of preference profile trend causal networks formed at each step measurement [7]. Information processing instrument contains questions about transport in plant with four indicators namely, information identification, information interpretation, relevance of information, and information application [11] while the knowledge instrument contains questions about transport in plant in general. Instrument knowledge done before learning process whereas MR and information processing instrument done after learning process the transport plant material. The analysis of quantitative data using linear correlation on a level of significance 5% whereas the qualitative data in the form of causal network is analyzed in a descriptive.

3. Result and discussion
Students’ mental representation and information processing during learning are based on diagram convention of transport plants [12] as shown in Figure 1. In diagram convention contained various information elements that help explain the transport process in plant through diagram. Transport plant defines as the process of displacement of water molecules absorbed from the soil by the roots to stem and leaves then out to the atmosphere through transpiration. Through the diagram convention of transport plant appears various patterns of students’ mental representation in the form of causal networks based on information elements contained in the diagram.
As seen in Table 1, results in research showed that mental representation has a strong correlation with the ability of information processing (r = 0.578) and knowledge (r = 0.679). Students’ understanding of the object depends on their mental representations [4]. Good mental representation is supported by good information processing and good knowledge of the concept. Diagram convention contains information and to understand it requires the information processing in working memory. While students are processing the information, the knowledge of related content needed to assist the construction of new knowledge that is being processed. This can be seen from the results of a high correlation between information processing with knowledge (r = 0.688) in Table 1. Meanwhile, when represent a diagram based on causal network there are causal interactions between information elements in the diagram. In linking one information with each other, it requires knowledge related to the content. Information processing and knowledge will be different on each individual. Thus the students’ mental representation will also vary and can be seen in Figure 2.

Table 1. Correlation between mental representation with information processing and knowledge.

|                | Mental Representation | Information Processing | Knowledge |
|----------------|-----------------------|------------------------|-----------|
| Mental Representation | Pearson Correlation | 1                      | 0.578**   | 0.679**   |
| Sig. (2-tailed)      | N                     | 27                     | 27        | 27        |
| Information Processing| Pearson Correlation   | 0.578**                | 1         | 0.688**   |
| Sig. (2-tailed)      | N                     | 0.002                  | 0.000     | 0.000     |
| N                  |                        | 27                     | 27        | 27        |

Based on the results of this study, there are two types of mental representation pattern, they are pattern 1 linear or straight and pattern 2 simple branching. The graph on Figure 2 shows that the...
pattern 1 most widely produced by the respondents (dominate) of 56%. The patterns are adapted based on causal network forms developed by Ito [13]. Linear or straight pattern refers to Markov chain causal network. Relationships between information elements in Markov chain pattern only in one direction or in other words an information element only be associated with another one information element. While a simple branching pattern refers to feedback control with a single measurement causal networks. This pattern shows the relationships between information elements more complex than Markov chain pattern. In this pattern, there is an information element associated with another two information elements.

Figure 2. The percentage of the MR patterns formed.

Causal network formed reflects someone’s mental representation pattern [6]. Causal network is the result of cognitive process when students represent an object. In addition through causal networks also can be seen how far can a person understands the information. A better person’s mental representation, then the causal network’s pattern formed will be more complex. It is also concerned with knowledge and information processing ability owned by the student. A good knowledge helps students process information thereby they understand the important information in diagram convention. Thus the students were able to link more information elements and discover the causal interaction between information contained in diagram. Differences causal network not only based on a pattern but also seen from the number of information elements contained on the pattern. In the same pattern, the respondent showed the steps in selecting, sorting, and connecting the information elements in different ways. Mental representation’s patterns formed can be seen in Figure 3 and Figure 4 below.

Figure 3. Mental representation pattern 1 linear/straight.
Causal networks 3a and 3b (Figure 3) have the same pattern namely linear pattern (Markov chain). In general respondents understood that transport in plant begins with uptake water by the root hair then it is transported to xylem until transpiration occured. However, the information elements on the causal network 3a less than information elements on the causal network 3b. On the pattern 3b, respondent understood about adhesion and cohesion in xylem that helped transport of water and transpiration through stomata pore. It can be shown that in pattern 3a, respondent is less able to understand essential information elements in the diagram and the linkages between one another information elements. However, there is little fault on pattern 3b because there is connection between the soil particle with root hair. There stated that the soil particle is absorbed by the root hair while the material absorbed by the root hair is water. Based on this information the number of information elements are not the only parameter in seeing student's understanding of diagram but also supported as well with the connectedness between information elements formed causal network. Through linear patterns above seen that the student less detail when connected the tissue with process of the transport of water.

![Image](image.png)

**Figure 4.** Mental representation pattern 2 simple branching.

On the causal network 4a and 4b (Figure 4) have the same pattern namely simple branching (feedback control with a single measurement). In this pattern the students are already able to connect information element with more than one another information element. On the causal network 4a there are some information elements not listed in diagram convention but the respondent represents a transport process in plant based on the organs including root, stem, and leaves. Based on this the students not too attentive to the information elements listed in diagram but only considered at the process of transport based on the sequence of the organ. However, students were able to connect with more than one information element such as adhesion and cohesion in stem, there are mesophyll and stomata in the leaves, and the water is absorbed by the roots are also found in mesophyll. Whereas on causal networks 4b, have seen a clear relationship between plant tissue and the process involved in it.
Students were able to relate the information elements between one another and understand the important information in diagrams of plant transport consist of water uptake from the soil, cohesion and adhesion on xylem, and transpiration. These processes are elaborated in more detail, starting from soil particles contained water molecules, then water is absorbed by the roots hair, then water is brought to the xylem up to the mesophyll cells, and finally transpiration through stomata. On the causal network 4b, process in the xylem is described clearly which there are cohesion and adhesion by involving xylem’s cell wall. These phenomena (cohesion and adhesion) can occur with the presence of hydrogen bond that pull the water molecule.

Pattern 1 (Figure 3) shows that the students have less knowledge related to the concept of plant transport than on pattern 2 (Figure 4) because lack of causal interactions between information elements. In addition pattern 2 has more number of information element than pattern 1. This shows that more information elements are choosen and link between one other information element to form a causal network, then the better causal network was formed. The more information is choosen, the more information processing occur in the working memory. Therefore the information processing in working memory is fundamental thing to represents someone’s mental [6]. In mental representation through the causal network based on diagrams convention, required an understanding of a diagram. By understanding the diagram, someone will identify the information element that thought it was important. Furthermore the information is integrated based on certain relationships with students knowledge. When a student has less knowledge about particular information, then student's ability to interpret the information elements in the diagram convention will be low [14]. Knowledge owned by the student also determines the mental representation’s pattern because each information element contained in diagram asserts the students to understand it.

4. Conclusion

Through the use of diagram conventions can help students to understand the plant transport concept based on their mental representation appeared. Ability of students in reading the diagram convention shows the activity of working memory based on causal networks. Mental representation’s patterns show the level of understanding the information in diagram convention. A person's mental representation is very influenced by the knowledge and ability to process the information. In order to represent the mental well, then it takes good knowledge and good information processing too.

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