Semantic networks as mental representation of students in reading images on cell biology

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Abstract. A semantic network is a network that represents semantic ties between concepts or a network of frames. It is also used as a type of knowledge representation. This study aims to obtain an overview of the student's mental representation; it's formed when reading the image on cell biology. Participants in the study were 31 students (age 19-20) of Biology Education in the 2018/2019 academic year who attended a Cell Biology lecture at a university in Jakarta, Indonesia. After attending Cell Biology lectures, student's mental representation was measuring. The instrument used to measure mental representation is a worksheet, a modified version of the mental representation measurement model with the CNET-Protocol. The images read by students consist of two pictures, namely the transcription initiation complex and the translation initiation complex. The results showed three semantic network patterns describe students' mental representations, and each student has a different pattern and quality of mental representation. Based on the research findings, biology educators are encouraged to train students to read pictures of biology.

1. Introduction

Representation is defined as something displayed to the mind; a picture, image, or description; a sign or emblem, photo, art or statue; and form or illustration. These meanings suggest that representations may be physical or mental, that they are symbolic (they stand for something else and that abstractness (for example, from images to linguistic descriptions) differs[1]. These meanings suggest that representations may be physical or mental. They are symbols that stand for something else and discuss abstractness, such as image transformation to linguistic descriptions.

Representation is classified into external and internal. An external representation is one that available in the environment, like the flag or blueprint. Meanwhile, the internal representations are unknown but instead kept in the audience or learner's mind. In cognitive science, the conventional term for an internal representation is defined as a mental representation designated from private thinking resulting from mental activities[2].

The mental representation involves imagining and thinking of things that are not perceptually present. The mind itself contains a significant network of meaning structures (CNMS) for information storage and a variety of other subsystems for the processing of information produced externally and internally (e.g., perceptual systems, behavioral systems, and a verbal system)[3].

Internal representations can be classified into at least three groups concerning visualizations: visual memory representations, visual imagery, and knowledge[2]. Visual memory is, as long-term memory
implies, a memory of what something looks like. Based on our perception of the object or event of interest, graphical images are constructed. Knowledge representations for objects provide several characteristics and their experiences and typically include parts of the contexts they are used (e.g., time, place, activities, goals, objectives).[2].

The mental representation can be transduced by external stimuli when learners studied a textbook, identified a picture, and carefully double-checked their observation data. The mental representations can also be translated to external representations through transferring processes such as communication using language. We retrieve our internal representations and try to replicate them in some external form when we sit down to write a research article, compose an e-mail, or plan a grocery list. First, note that from external presentations, we also always seek to construct mental representations[2].

Furthermore, mental representations can interact with external representations in scientific pedagogy. One required field of interest in scientific pedagogy is how numerous external representations can interact with mental representations. Latest studies on the embodied view of cognition show that our desire to participate in world behavior significantly activates our thought. Our internal representations are not modal (propositional) but are associated with spatial cognition's perceptions and actions[4]. One direct implication of the embodied view is that the learner's experiences and behaviors connect several external representations to internal representations[5].

In biology classrooms, the external representations can be transferred to the internal one by introducing students to knowledge through various methodologies, including lectures, discussions, readings, lab experiences, and symbolic experiences. Biology classrooms teach complex topics. The purpose of these activities is to help students create internal representations of course material, store the information in memory to be used for further actions such as generate inferences, solve the problems, and make some choices.

This internal representation is built based on a causal network between knowledge elements and is only formed under certain time limits and circumstances. The causal network defines the objects' awareness facing all students and helps determine and make decisions about these objects. The development of a causal network is closely linked to the output of working memory in processing existing knowledge and, according to a given stimulus, integrating it with new information until the information is eventually represented[6]. Working memory, however, has a limited capacity that can impede the representation of several data so that only details or aspects are more in line with the understanding that students already have several pretend[6]. The mental representation that is mainly developed defines cognitive systems' creation and students' comprehension[7].

Images of external representations derived from mental representations can be divided into a causal network and semantic network. As mental representations will endorse causal reasoning, causal networks have been commonly used[8]. Causal networks can illustrate students' knowledge of objects or images. Therefore, it is useful for assessing how students make decisions about the information[6]. Meanwhile, a semantic network is a network that reflects semantic connections among concepts, or a frame network. It is also used as a type of representation of information[9].

As a net-like graph, a semantic network or net reflects the information. A composite structure of an idea, event, condition, or entity is almost always represented in a semantic network, through the corresponding type of nodes representing conceptual units (drawn as circles or boxes) and directed connections representing the relationships between the units (drawn as arrows between the nodes).[9]. An example of a causal network is shown in Figure 1a[10], and a semantic network is shown in Figure 1b[9].

Figure 1a shows that whether or not a car starts is caused by its battery and fuel supply state, that whether or not a car move is forced by whether or not it starts, and that there are no reasons (in this model) for the battery condition and the fuel supply. We assume that all variables are binary in this case[10].
Figure 1. (a) A causal network, (b) a semantic network, both are images of external representations of mental representations.

Figure 1b has a hierarchical graph describing two entities with their claimed attributes and relationships (Toby and the unidentified tigers), on top of which there is an abstract hierarchy of more general definitions and relationships. From this combined framework, data about the composite purpose as a whole and its comparisons to other ideas can be collected [9].

An abstract (graph-theoretical) network may be diagrammed, mathematically defined, computer-programmed, or electronically hard-wired. When you allocate meaning to each node and connection, it becomes semantic. Semantic networks aim to represent all data expressed in natural language, unlike specialized networks and diagrams. [9].

Paivio revealed that mental representation depicts information in a framework formed through communication with objects that include visual data and verbal data (a dual coding approach)[1]. The mental representation level is obtained from the relevance of causal network information [6]. To measure mental representations of Arentze et al. developed a semi-structured interview method called CNET (short for Causal Network Elicitation Technique)[6]. The CNET-Protocol is directed to describe how a person's mental representation makes decisions about a problem (decision problem).

In the cell biology course, various cell organelles’ structures and functions are discussed with ultramicroscopic size. The concepts presented in cell biology are abstract. Multiple representations are used in cell biology lectures, such as two-dimensional and three-dimensional images, diagrams, and animations. However, several students have trouble grasping abstract biological concepts because the human mind does not respond to abstract representations in the best possible way. [5].

In various textbooks, reference sources for cell biology courses are always presented with illustrated images that explain the concept being studied. Reid states that images are beneficial in narrating biological concepts[11,12]. The combination of text and pictures is following the dual coding theory, that there is an interaction between visual data (images) and verbal data (text)[1].

Pictures play an important role in understanding science concepts, including biology; in education, representation, understanding, and reading, images are significant, particularly in learning activities [13]. Previous research has revealed that students’ mental representations have different patterns when reading spatial isomorphism diagrams and convention representations. The formation of mental representations and students’ ability to interpret the components of information in images are essential aspects of understanding an image [14]. Other studies have shown that diagrammatic interpretation can shape a person’s mental representation [15].

Related research findings indicate that variations in the pattern of mental representation expose the differences in how students begin to discover essential information in the diagram to construct a causal network and from which point. Further study reveals that the mental representation pattern's variation is related to how complex the information found in the diagrams/images is processed by the students [16]. Most students can only connect information components in linear form on the image, and a few students create reciprocal relationships on the convention diagram between information
Other studies that measure teachers' mental representation have shown that compared to a teacher with a facilitator teaching style, a teacher with an expert teaching style appears to have a robust mental representation [18].

This study was conducted to analyze students' mental representations when reading pictures in a cell biology lecturer. The research objective directed to obtain students' mental representation using semantic network approaches in reading images afterward attending cell biology lectures.

2. Method
This research method is descriptive research. The research sample was determined purposively. Participants were 31 students (age 19-20) in semester 3 of the 2018/2019 academic year who took cell biology lectures at a university in Jakarta, Indonesia. The images read by students consist of two pictures, namely the transcription initiation complex (Figure 2) and the translation initiation complex (Figures 3)[19]. A writing instrument is used in the form of a worksheet that adapts the CNET protocol, a tool generated by Arentze, to explain students' mental representation while reading pictures[6].

Following CNET Protocol, the worksheet consists of four interrelated steps. The first step to the fourth step refers to the biological images presented in the worksheet. The four steps are as follows. The first step is the determination of information elements. In this section, students are asked to determine or select essential information elements in the picture; then, students are asked to sort the information elements. Second, the establishment of semantic networks. In this section, students are asked to determine whether the order of the information elements is correct and whether the sequence of these information elements has a relationship. Third, determination of probability parameters. In this section, students were asked to describe the network or relationship between the information elements found in the image. Fourth, determination of usability parameters. In this step, students determine their choice of network profiles by ensuring whether what has been done in the first to third sections is correct (according to students) [14].

Figure 2. Transcription initiation complex.
Qualitative data is the result of the analysis to explain the generated semantic network pattern based on the Bayesian Network [20]. A probabilistic graphical model representing knowledge about a new domain where each node corresponds to a random variable is a Bayesian network (BN). For the corresponding random variables, each edge represents the conditional probability. Semantic network patterns are analyzed using topological sequences representing different patterns at the semantic network level.

Figure 3 shows the Bayesian network pattern shape, first Markov chain pattern; second, the feedback control with a single measurement; and third, repeated feedback with multiple adaptive measurement[20].

3. Result and Discussion
The research findings of students' mental representations in reading images of transcription initiation complex images and translation images' initiation showed variations in the semantic network pattern. The mental representation in reading images of the transcription initiation complex (Figure 2) and the translation initiation complex (Figures 3) is formed by defining the information elements and ordering them accordingly and creating a semantic network relationship between the information elements.
The findings show three patterns formed, pattern one Markov chain, pattern two the feedback control with a single measurement, and pattern three repeated feedback with multiple adaptive measurements. The percentage of pattern formation from students' mental representations can be seen in Figure 5a and Figure 5b.

In Figure 5a, it can be seen that Pattern one dominates with a percentage of 42%. Pattern one consists of respondents who can form patterns such as workflows or processes that involve all or several elements of information in a transcription initiation complex image, as shown in Figure 6.

**Figure 6.** Example of a student's mental representation of pattern one.

The information has also been obtained in Figure 5b that pattern two dominates with a 42% higher percentage than pattern one and pattern three. Pattern two consists of respondents who can create a flow pattern between information elements but are still in a relationship that involves an information element or multiple information structure elements, as shown in Figure 7.
Figure 7. Example of a student's mental representation of pattern two.

In Figure 5a and Figure 5b, pattern three shows 13% and 10%, respectively. Pattern three consists of respondents who can form different flow patterns involving more than one information element or several elements of the information structure, shown in Figure 8. Pattern three reveals a more complex representation. The variety of patterns will vary depending on the students, depending not only on the completeness of the knowledge elements in the image but also on the perception of the reading of the students' image and the experience they had before.

Figure 8. Example of a student's mental representation of pattern three.

Based on the completeness and sequence of information elements and the relationships between information elements, the three representation variations are established. For each student, the study showed that variations in semantic networks are different. Representation patterns would contribute to the establishment of semantic networks. The processing of information (information processing) in working memory influences the establishment of semantic networks, as the functioning of working memory affects mental representation. [6].

The results of the analysis and grouping of student representation patterns in images of the transcription initiation complex (Figure 2) and the translation initiation complex (Figures 3) show that accuracy in assigning and ordering information elements is based on the mental representation patterns that are formed [14]. The inaccuracy in determining the elements and sequences of information elements is related to the quality of the formed causal network [6]. The creation of causal networks is determined by the processing of information in working memory, as working memory also affects mental representations[6].

Based on the information in Figure 5a, it is known that there are 10% of students in the failed category, while in Figure 5b, there are 9% of students in the failed category. Included in the failed
category are those who incorrectly determine the correct information element, do not provide logical reasons, and cannot show the relationship between the selected information elements. These findings indicate that there are still many students who have difficulty identifying an image. It suggests to educators the importance of teaching and guiding students in reading a picture. However, based on Reid's research, this isn't very easy by how images and text interact in students' minds [11]. It shows that not all students are able to interpret the data on the image with a high degree of sophistication, proven with different formation patterns of representation.

The difference between the representations created by the pattern demonstrates the complexity of the image in the form of causal networks representing the students[16]. Early on, when a picture with high complexity is given, it takes on a knowledge base to understand the picture. The image is represented by the students' interpretation of the pattern. Lack of prior knowledge of a notion or information kept by students may reduce the ability of students to understand the information element in a diagram/photo. [21]. Three variables affect the creation of a mental representation, i.e., students' prior experience, the perception of the image by students, and the ambiguity of the images presented. To correctly identify each element of the content, mental representations required an excellent prior understanding of the picture[16].

4. Conclusion
In reading the cell biology picture, students' mental representation is shown by the semantic network pattern created. The findings showed that there were three semantic network patterns. The results of this study provide recommendations for teachers to train students in reading the information contained in biology pictures.

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