Asian Journal of Biology Education, 2024
https://doi.org/10.57443/ajbe.16.0_9

Research Note

A Preliminary Study on Effect of Providing Linking Words in Concept Mapping for Representing Cell Biology Knowledge

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(Received: 23 August 2023; Accepted for publication: 21 January 2024)

Concept mapping is an established method to create a network of knowledge. Concept map is made of interconnected propositions in which each proposition comprises of two concepts connected with linking words. The article is to study effect of providing linking words in concept mapping for representing cell biology concepts, comparing with traditional concept mapping among college biology students. A criterion concept map was used to evaluate concepts, linking words and valid propositions. The students' concept maps were scored for structural complexity and propositional validity. The students' propositions where they used the provided linking words showed a higher proximity percentage with criterion concept map as compared to concept maps without the provided linking words. We discuss the pedagogical implications of our study for understating or forming biological concepts with linking words in concept mapping.

Keywords: *biological concepts, cell biology, concept mapping, language of science, linking words*

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INTRODUCTION

Concept mapping method is a two-dimensional graphical representation of concepts connected with linking words organized in hierarchical levels with branches and cross-linkages (Novak and Gowin, 1984; Mintzes *et al.*, 2000; Novak, 2010; Canas *et al.*, 2015). It is based on the Ausubel's classroom learning theory of subsumption. The branches indicate progressive differentiation, and the cross-links indicate integrative reconciliation (Ausubel, 1978). It incorporates higher-order cognitive skills (Briggs *et al.*, 2016; Canas *et al.*, 2017) because students assimilate new knowledge into their existing framework of knowledge, in contrast to memorizing facts that require low-level cognitive skill (Momsen *et al.*, 2010). It has been successfully used in classroom learning for: mapping knowledge (Pearsall *et al.*, 1997; Hay *et al.*, 2008); assessing student understanding in biological science (Briggs *et al.*, 2016); in classroom and laboratory (Kaiser, 2010), and in novice-expert studies (Kinchin, 2001; Chi, 2006; Mintzes and Quinn, 2007; Briggs *et al.*, 2016; Price *et al.*, 2021; Lee *et al.*, 2022), and has established reliability and validity (Ruiz-Primo *et al.*, 2001).

The rationale of providing linking words in concept mapping is to facilitate expert-like thinking. Experts not only use appropriate linking words, but also use a diversity of linking words, while novices use linking words that often are inappropriate, using similar linking words for variety of meaning resulting in ambiguity (Kinchin, 2000). As one of the characteristics of an expertise is focusing on links, we adopt concept mapping with specific set of linking words facilitating students in expert-like thinking, serving as scaffolding in classroom learning (O'Donnell *et al.*, 2002). Studies indicated that providing linking words along with concepts during concept mapping helps to depict much greater number of valid propositions, facilitating disambiguity, consistency in representing knowledge (Kharatmal and Nagarjuna, 2016). Considering the significance of focusing on linking words, we investigated the effect of providing linking words in concept mapping for representing cell biology concepts.

METHODOLOGY

Participants

A voluntary participation of nine college biology students (18-20 years, with informed consent) were part of the study. The instructional program of teaching concept map began with the instructor introducing the tool with its features. A familiarization task on creating concept maps for introducing the elements of concepts, propositions, branches, hierarchy, cross links, scoring rubric was conducted to the students before the study. Students also worked out certain trial or practice concept maps on topics of 'food', 'transport system', from which it was ensured that students have learned the concept mapping tool. Further, a textbook (NCERT, 2007) passage on plastids was used to create concept map with the traditional method without providing linking words. This was followed by creating concept maps by providing linking words: includes/kind of, contains, known as; has function/has role; has shape; has size; has color.

Analysis of concept maps

The criterion concept was created in collaboration with teachers and researchers in consensus. The main concept is at the top and the concepts are linked with linking words to another concepts. A concept can be branched further into two to more concepts depicting progressive differentiation of the concepts. The concept map begins with a general concept and differentiates into more specific concepts by subsumption creating hierarchical levels. Some concepts from one domain are linked to another domain depicting integrative reconciliation and therefore cross links are scored highest. These conventions were part of the concept mapping familiarization task and creating criterion maps.

Both types of students' concept maps were compared with a criterion map. These maps were evaluated and scored for structural complexity (the total number of propositions used) and propositional validity (number of valid propositions/total number of propositions) based on the established scoring rubric (Novak & Gowin, 1984; Novak, 2010).

The scoring rubric follows as: 1 point for each non-redundant concept; 1 point for each proposition, 5 points for hierarchy, 10 points for cross links. Some research studies have also scored each branching for 3 points. However, for the current studies, the concept maps were scored and analysed for number of propositions only. Figure 1 shows the criterion concept map; Figure 2 shows a representative student's concept map on plastids without provided linking words. Figure 3 shows a representative student's concept map on plastids with provided linking words. A score of 1 point was assigned for each proposition, for example, "plastids contain chlorophyll pigment", "plastids are part of plant cells".

RESULTS

From the list of 20 propositions of criterion concept maps were used to compare the valid propositions of each student's concept maps from both the methods of without providing and with providing linking words. The percentage of valid and matching propositions was calculated for each student's concept maps to indicate a proximity percentage. The score for propositional validity was used to determine a proximity percentage to criterion

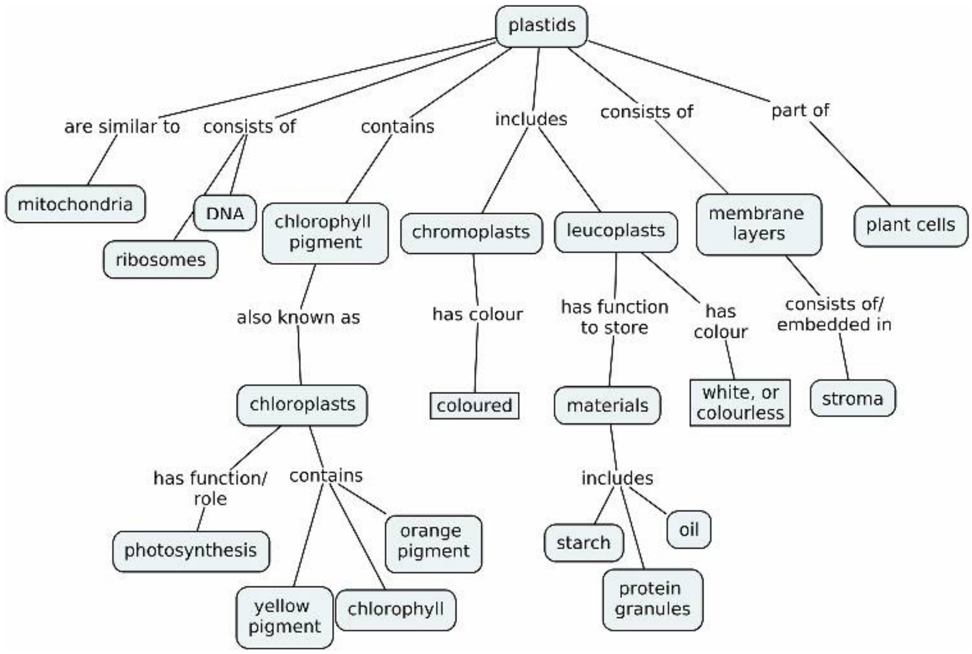

Figure 1: An expert's concept map on Plastids created by group of teachers in consensus from the textbook

Concepts are in boxes – plastids, ribosomes, DNA, mitochondria, etc. Linking words are used for connecting two or more concepts – consists of, contains, includes, part of, etc. A proposition is comprised of concepts and linking words - Plastids contains chlorophyll pigment.

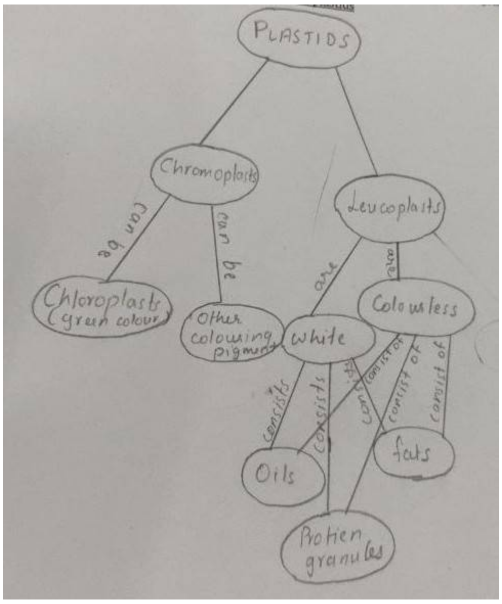

Figure 2: A student's concept map on Plastids created with no linking words provided

concept map. This was achieved by counting the percentage from total number of valid propositions that were matching with the criterion concept map (20 number of propositions). For example, if a student has a total proposition of 13 and from these there are nine invalid and four valid propositions (as in criterion concept map), then the proximity percentage was calculated as 31%.

The score of propositional validity of each student was quite high and showed a greater proximity percentage (Figure 3) due to the usage of the provided linking words that enables to create more valid, unambiguous propositions. The findings from this study indicated concept mapping with provided linking words facilitated towards students' higher proximity to expert's representations.

DISCUSSION & IMPLICATIONS

We used the established concept mapping method with a suggested addition to the method of providing linking words. Traditionally in the con-

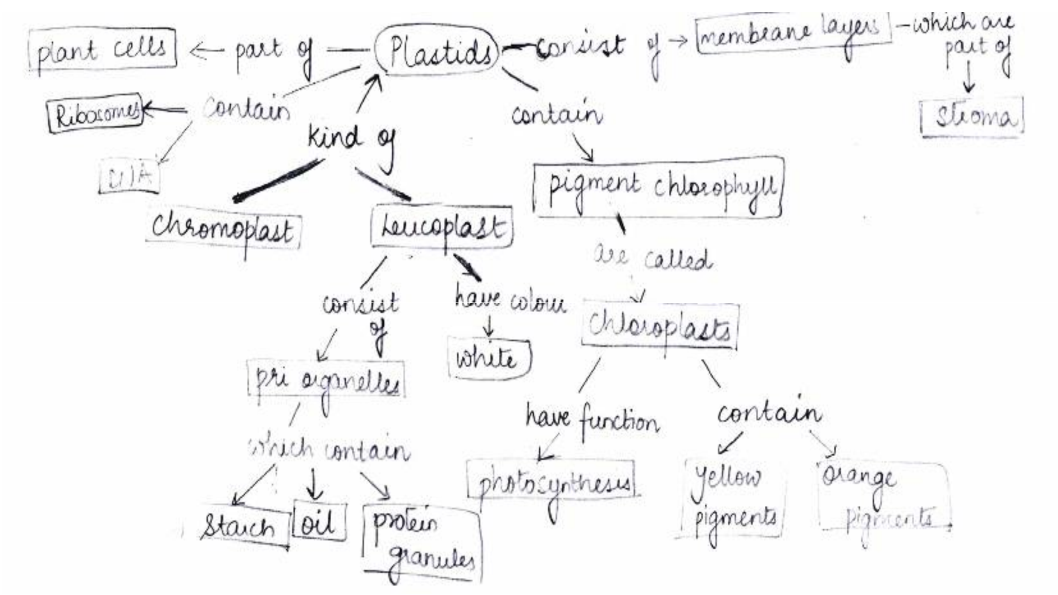

Figure 3: A student's concept map on Plastids created using the provided linking words

cept mapping method there is freedom in choice of linking words, whereas in our method we have provided the linking words. This was due to the focus on disambiguation and consistent use of the linking words that are meaning providers in the concept map.

It can be noted that without provided linking words, students used ambiguous and vague linking words such as has, can be, etc. However, in contrast, the provided linking words – part of, includes, etc. not only serves as scaffolding but also facilitate in expert-like representation of valid propositions. The same set of linking words would be sufficient even for representing a wider domain of knowledge. Further studies that can be based on a larger classroom for finding the statistical significance. The objective of the current study has been to find the effect of providing linking words and it is observed that it facilitates and is not a constraint in representing biology knowledge.

Concept mapping has been effectively used in conceptual learning, misconceptions research in biological sciences. These studies were focusing on the concepts while our study focuses on both concepts and linking words as we believe that the nature of linking words convey the scientific validity in a proposition. In our study, when we introduced the linking words to map a topic, these facilitated for students in organization of knowledge. We suggest that this also can help to facilitate in learning the jargonified biology terms by mapping knowledge. The educational implications of focusing on linking words not only helps to weed out ambiguities but also helps in consistency for mapping biology knowledge and scientific knowledge in general. As pedagogical implication, this method can facilitate teachers in creating teaching-learning material.

ACKNOWLEDGEMENTS

We thank all students for volunteering for study. We have no conflicts of interest. We acknowledge the support of the Department of Atomic Energy, Government of India, to TIFR under Project Identification No. RTI4001.

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