Innovating with Concept Mapping
Proc. of the Seventh Int. Conference on Concept Mapping
Tallinn, Estonia 2016

# CASE STUDIES AND EFFECTIVENESS OF A CMAPS ANALYTICAL METHOD

*Masaru Taga, Ryukoku University, Japan*
taga@agr.ryukoku.ac.jp

**Abstract**. Analytical assessment of concept maps (Cmaps) using Fisher's exact test was performed to detect changes in high-school students' perception of scientific concepts in a science class. By counting the number of links between two words (concepts), AMCL (Analytical method of Cmaps with the increase and decrease of links) reveals whether the increase and decrease of these links are consistent with the results of Fisher's exact test, which uses 2 × 2 cross-tables for such calculation. I verified the effectiveness of AMCL using three case studies from high-school earth science classes: examining the fossil footprints of Akebonozou, a Pliocene elephant species (case study 1); studying the gravel debris paleoflow (case study 2); and investigating a caldera in Japan (case study 3). Links between two or three words (concepts) in Cmaps which correspond to various scientific concepts were selected and used in AMCL. Based on the case studies, the AMCL statistical analysis can be effectively used for detecting the tendency of different understandings of all students in the class.

## 1 Introduction

Concept maps (Cmaps; Novak and Gowin, 1984) have been used for detecting changes in perception. In Japan, since the 1980s, Cmaps have been used to evaluate the levels of understanding and knowledge obtained by a learner, supporting the teaching process. In addition, they have been used as tools to support collaborative learning with others, including a teacher. Moreover, various applications have been suggested by creating Cmaps using a computer. In the present study, the effectiveness of the AMCL method (Analytical method of Cmaps with the increase and decrease of links), developed by Taga et al. (2007), is investigated. The AMCL method enables the detection of changes in the perception of scientific concepts using Fisher's exact test based on the increase and decrease of the linkage of Cmaps. In the present study, the effectiveness of this analytical method is determined based on three case studies from science classes (Taga, 2008; Taga et al., 2009; and Taga et al., 2010), though Cmaps of this study are not Novakian.

## 2 AMCL Methodology

Generally, Cmaps presented at the beginning and end of a lesson can help students grasp changes in scientific concepts through comparison. However, it is difficult to grasp general transformation tendencies of these understandings as a whole, especially when there are many target students. Therefore, Taga et al. (2007) focused on linking two or three words in Cmaps. By counting the number of links (connection between these two or three words as one unit), they statistically analyzed the numerical change in understanding before and after the lesson (AMCL). The AMCL method is outlined as follows.

After performing Cmaps twice (i.e., before and after) by focusing on particular meaningful content before and after a class, the number of "word–word" links, which is considered as a proposition, is counted. Then, the increase or decrease is examined at a 5% significance level (two-sided test) using Fisher's exact test by employing a 2 × 2 cross-table. When the increase or decrease is significant at the 5% level, then the probability of the proposition with two or three concepts ("word–word" or "word–word–word") is assumed to increase. As a result, it is possible to infer the general tendency toward a change in perception by the entire class. AMCL is usable about the change of various propositions, and this report examines the effectiveness of AMCL.

## 3 Case Studies of AMCL Application

In earth science classes of Japanese senior high schools, the AMCL method is used for detecting changes in students' perception of scientific concepts. A student's Cmaps are shown in Figures 1, 2, and 3 and respective 2 × 2 cross-tables are shown in Tables 1, 2, and 3.

### *3.1 Case Study 1 (Taga, 2008)*

Fossil footprints of Akebonozou, a Pliocene elephant species of Japan, were discovered in the Shiga prefecture, Japan (Research Group for the Fossil Footprints of Yasugawa, 1995). In junior high-school classes, the history of the ancient Biwa Lake layer, investigation method, classification of elephants, and formation of the fossil footprints of Akebonozou have been taught to students. Thus, students deepened their understanding concerning the formation of such fossil footprints. At the same time, students appear to comprehend concepts connected to sedimentation. To verify which concepts they understood, before and after a particular lesson, I recorded students' conception of a subject under study using Cmaps (Novak and Gowin, 1984). In particular, I focused on the increase or decrease of perceived links between different concepts regarding stratum formation. For verification, the conceptual system in which two or more conceptual labels are connected was used, i.e., "a footprint is printed on mud," "sand is deposited by heavy rain," "sand is deposited on the footprint," and "an alternation of sand and mud forms when sand and mud are deposited in turns." Furthermore, statistical analysis revealed changes in conceptual systems. After the class, each conceptual system considerably increased at the 5% significance level. This suggests that students understood the formation mechanism of the stratum in an alluvial plain in the context of the Earth's system.

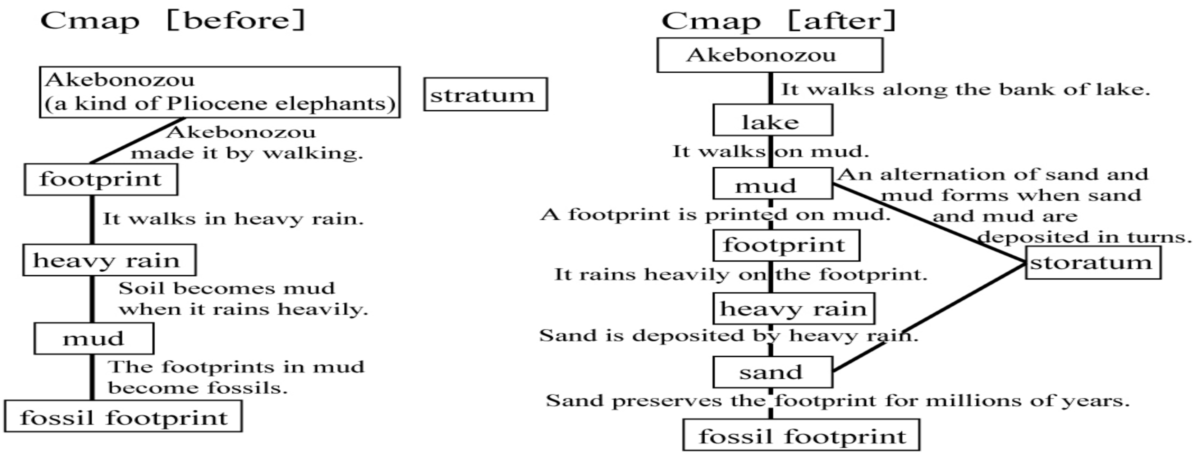


**Figure 1**. Student's Cmaps illustrating his/her understanding of fossil footprint formation before and after the lesson (Taga, 2008).

N = 23.

| mud — footprint 「A footprint is printed on mud」 | Number of links obtained | Number of links not obtained |
|---|---|---|
| Concept Map [before] | 4 | 19 |
| Concept Map [after] | 16 | 7 |

p = 0.0008 ($p < 0.05$) meaningful increase

| footprint — sand 「Sand is deposited on the footprint」 | Number of links obtained | Number of links not obtained |
|---|---|---|
| Concept Map [before] | 3 | 20 |
| Concept Map [after] | 17 | 6 |

p = 0.0000 ($p < 0.05$) meaningful increase

| heavy rain — sand 「The sand is deposited by heavy rain」 | Number of links obtained | Number of links not obtained |
|---|---|---|
| Concept Map [before] | 0 | 23 |
| Concept Map [after] | 7 | 16 |

p = 0.0091 ($p < 0.05$) meaningful increase

| mud-strutum-sand 「An alternation forms when sand and mud are deposited in turns」 | Number of links obtained | Number of links not obtained |
|---|---|---|
| Concept Map [before] | 5 | 18 |
| Concept Map [after] | 13 | 10 |

p = 0.0331 ($p < 0.05$) meaningful increase

**Table 1:** 2 × 2 cross-tables of the stratum formation process (Taga, 2008).

### *3.2 Case Study 2 (Taga et al., 2009)*

Gravel debris flow in the Plio–Pleistocene Kobiwako Group, which is distributed over the southern part of Shiga, Japan, was observed during a practical lesson in high-school science classes. During this lesson, students compared the gravels of the debris flow with those from a river and discussed how the shapes of gravels were formed. I examined changes in students' understanding by AMCL (Fig. 2 and Table 2). Through the lesson, students' understanding of debris flow formation deepened. Therefore, this observation lesson was effective for understanding the debris flow.

### *3.3 Case Study 3 (Taga et al., 2010)*

A practical lesson was conducted in a senior high-school earth science class on the analogue models of the Biwako Cauldron caldera, which is located in the southern part of Shiga, Japan. During the lesson, students observed the analogue models of caldera formation and discussed how the shape of the caldera was formed. Changes in the understanding of the lesson's contents by students were examined through Cmaps by AMCL (Fig. 3 and Table 3) and protocol in discussion and questionnaire method. As a result, students' understanding of the caldera formation process was enhanced. Therefore, the two observation models are effective in revealing the caldera formation process. Moreover, the discussion by students was significantly effective.

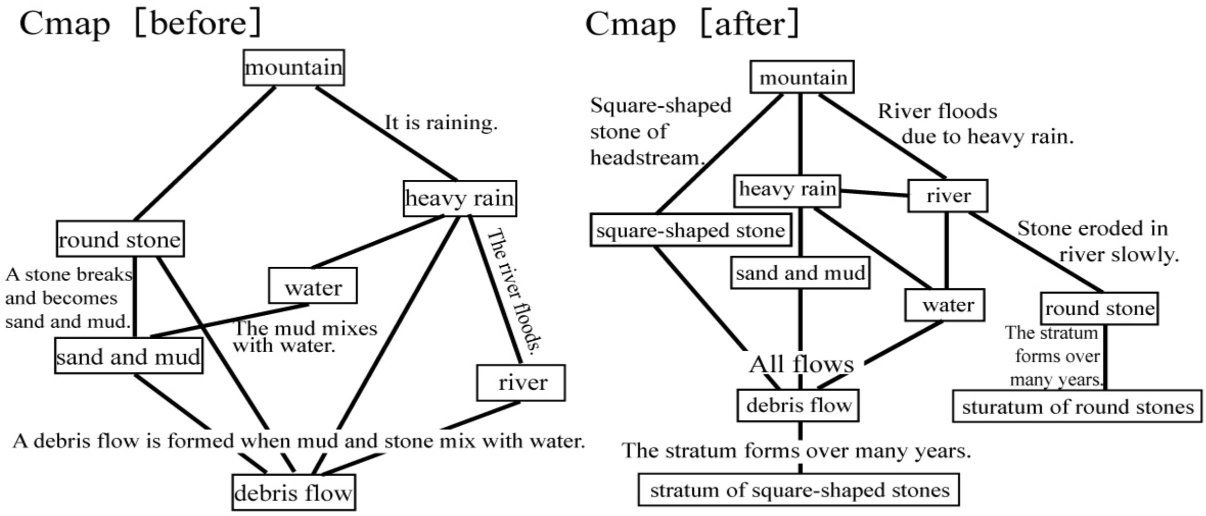


**Figure 2**. Student's Cmaps illustrating his/her understanding of debris flow before and after the lesson (Taga et al., 2009).

N = 71.

| debris flow—square-shaped stone 「Square-shaped stone forms due to debri flow」 | Number of links obtained | Number of links not obtained |
|---|---|---|
| Concept Map [before] | 20 | 51 |
| Concept Map [after] | 52 | 19 |

p = 0.0000 ($p < 0.05$) meaningful increase

| river—round stone 「Round stone forms due to river flow」 | Number of links obtained | Number of links not obtained |
|---|---|---|
| Concept Map [before] | 21 | 50 |
| Concept Map [after] | 41 | 30 |

p= 0.0012 ($p < 0.05$) meaningful increase

**Table 2:** 2 × 2 cross-tables of concepts concerning the debris flow process (Taga et al., 2009).

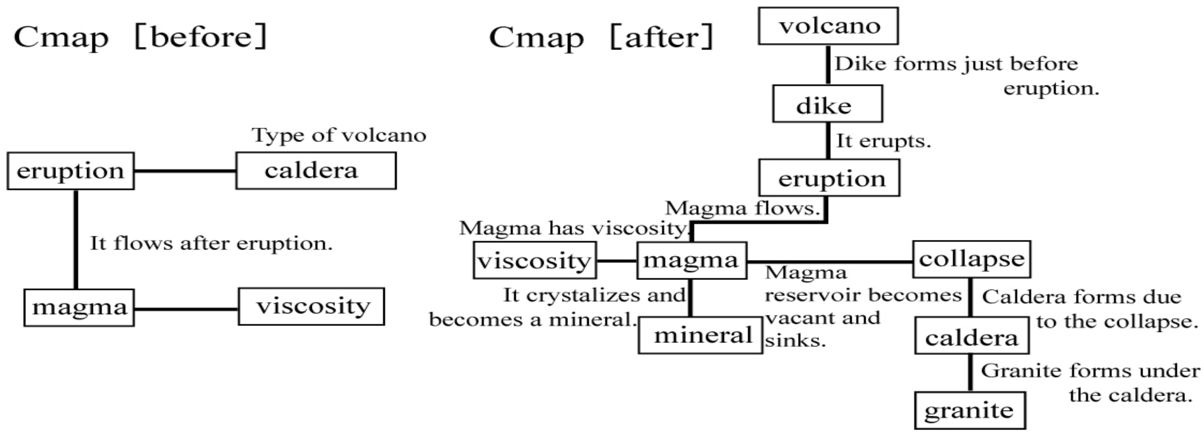


**Figure 3**. Student's Cmaps illustrating his/her understanding of the caldera formation process before and after the lesson (Taga et al., 2010).

## 4 Discussion

Novak and Gowin (1984) reported that "Concept maps are intended to represent meaningful relationships between concepts in the form of proposition. Propositions are two or more concept labels linked by words in a semantic unit. In its simplest form, a concept map would be just two concepts connected by a linking word to form a proposition." Therefore, the link connecting two labels is the simplest unit of a Cmap and corresponds to a proposition. The AMCL method can verify the increase or decrease of Cmap units.

N = 27.

| eruption—dike 「It erupts through dike」 | Number of links obtained | Number of links not obtained |
|---|---|---|
| Concept Map ［before］ | 2 | 25 |
| Concept Map ［after］ | 9 | 18 |

$p = 0.0394$ ($p < 0.05$) meaningful increase

| dike—caldera 「Caldera forms due to dike」 | Number of links obtained | Number of links not obtained |
|---|---|---|
| Concept Map ［before］ | 2 | 25 |
| Concept Map ［after］ | 9 | 18 |

$p = 0.0394$ ($p < 0.05$) meaningful increase

| dike—collapse 「collapsed along dike」 | Number of links obtained | Number of links not obtained |
|---|---|---|
| Concept Map ［before］ | 1 | 26 |
| Concept Map ［after］ | 8 | 19 |

$p = 0.0243$ ($p < 0.05$) meaningful increase

| collapse—caldera 「Caldera forms due to collapse」 | Number of links obtained | Number of links not obtained |
|---|---|---|
| Concept Map ［before］ | 7 | 20 |
| Concept Map ［after］ | 16 | 11 |

$p = 0.0266$ ($p < 0.05$) meaningful increase

**Table 3:** 2 × 2 cross-tables of concepts concerning the caldera formation process (Taga et al., 2010).

In the abovementioned three case studies, the number of links corresponding to propositions changes after a lesson. Thus, links in each student's Cmaps also change. Individual changes can be understood more easily than those of the entire group of students by comparing Cmaps before and after a lesson (Fig. 1, 2 and 3). However, general tendencies affecting the entire group of students are difficult to grasp. The three case studies provide evidence that the AMCL method can be used for statistically detecting these general tendencies. In the three case studies, new links were formed after a lesson, which did not exist in Cmaps before the lesson (Table 1, 2 and 3). These new links refer to new connections among concepts. This means that new propositions (scientific concepts) were formed and the AMCL method effectively detected this change. In this sense, the AMCL method would be an effective analytical method.

## 5 Summary

For detecting changes in propositions (scientific concepts), I verified the effectiveness of the AMCL method, which analyzes the number of links in Cmaps obtained before and after lessons. This conclusion was verified through three case studies of science classes in a Japanese high school. Results revealed that the AMCL method can detect changes in the tendencies of an entire study group of students.

## 6 Acknowledgements

This work was supported by JSPS KAKENHI Grant Number 16K04725.

## References

Novak, J. D., & Gowin, D. B. (1984). Learning How to Learn. New York: Cambridge University Press.

Research Group for the Fossil Footprints of Yasu-gawa (1995). Fossil Footprints of Kobiwako Group at Yasu-river (Kosei-cho, Japan). Research report of the Preparatory Office for Lake Biwa Museum, 3, 1-134 (in Japanese).

Taga, M. (2008). Conceptual Changes in Understanding the Earth System in Earth Science Class Based on Teaching Material Using Fossil Footprints of Stegodon aurorae (Akebonozou). Education of Earth Science, 61(2), 35-47 (in Japanese).

Taga, M., Kubota, Y., & Nakano, S. (2010). Development and Evaluation of Analogue Model Experiments for Understanding the Formation of Caldera: Lesson for Upper Secondary School students "Biwako Cauldron, Shiga." Journal of Research in Science Education, 51(1), 83-91 (in Japanese).

Taga, M., Kubota, Y., & Nishikawa, J. (2009). Development and Evaluation of Teaching Materials for Understanding the Debris Flow with Gravels in the Kobiwako Group: the Observation Lesson "Square-shaped Gravels and Round Gravels." Journal of Research in Science Education, 49(3), 67-78 (in Japanese).

Taga, M., Nishikawa, J., Kubota, Y., & Kusachi, I. (2007). Development and Evaluation of Teaching Materials for Understanding Crystallization Differentiation. Journal of Research in Science Education, 47(3), 15-22 (in Japanese).