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# Propositional-Level Analysis of Collaborative Learning with Kit-Build Concept Map

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**Abstract:** Typically, classroom practices in the collaborative learning context center around three distinguishable levels of activity: individual activities, group work, and whole-class discussion. It is important to identify and analyze the correlation between these levels to enable teachers to understand and improve the dynamics of students' understanding in the context of collaborative learning. This study proposes a method based on the Kit-Build concept map (KBmap) to analyze the relation between individual activities and group work in the classroom. The KBmap is a type of close-ended concept map that provides decomposed concepts and links from the concept map made by a teacher. This mechanism enables teachers to assess students' understanding, and facilitate the coordination of learning in the classroom. To evaluate the proposed method, a junior high school in Japan is used as case study.

**Keywords:** concept map, kit-build, classroom orchestration, learning analytics

## 1. Introduction

One of the core roles of teachers in the classroom is that of the coordinator of classroom discussion. Therefore, it is necessary for them to monitor students' understanding or perspectives, and facilitate classroom discussion. Essentially, a teacher manages the classroom by orchestrating the integration of individual activities, teamwork, and whole-class activities (Dillenbourg, & Jermann, 2010; Dillenbourg, 2013).

There are several methods of monitoring collaborative learning; some of these methods include evaluating the students' understanding using rubrics, analyzing their learning activities step by step, and discourse analysis. Technology plays an important role in enabling teachers to monitor the activities of learners. Martinez-Maldonado et al. propose and develop a multi-tabletop classroom and dashboard to support collaborative learning (Martinez-Maldonado, Clayphan, Kay, & Yacef, 2014). Their study provides a special environment for learners to work collaboratively with concept maps, and for teachers to access their verbal and physical interactions. Matsuzawa et al. propose a tool for exploring the network structure of collaborative learning discourses (Matsuzawa, Oshima, Oshima, Niihara, Sakai, 2011). This tool visualizes the dynamics of the network structures of learners, discourse units, and words.

This study proposes the analysis of learners' understanding based on concept mapping and collaborative learning at the propositional level, that is, through the propositions they make. Similar to KBDeX, the analysis is content-oriented (Hoppe, 2017); however, the unit of analysis, words or propositions, is different. Concept mapping is a popular way of representing learners' state of understanding (Novak, & Cañas, 2006). A concept map is a generic name for the graphical representation of the process of organizing and representing knowledge or understanding. Novak's definition of the concept map is particularly well known. Generally, concept mapping is predicated on building concept maps based in an open system without restrictions using arbitrary nodes and links. In this method, simple components, nodes, and links represent concepts and their correlations are emphasized. Although concept maps can be a tool for individual learners to reflect on their understanding and thereafter communicate their understanding to others (Tergan, 2005), they are difficult to analyze (Herl, O'Neil, Chunga & Schacter, 1999).

The Kit-Build concept map (Hirashima, Yamasaki, Fukuda & Funaoi, 2011; Sugihara, Osada, Nakata, Funaoi & Hirashima, 2012), subsequently referred to as the KBmap, can automatically analyze concept maps, because learners create concept maps from components that are decomposed from the concept maps created by teachers. Using these components, learners can organize their understanding in a comprehensible way in the form of concept maps, thus enabling teachers to assess their understanding immediately (Hirashima, Yamasaki, Fukuda, & Funaoi, 2015). The KBmap assessment method is automatic, and its validity for evaluating learners' understanding has been confirmed (Wunnasri, 2018). In addition to the one-on-one comparison, it is possible to merge the maps of individual learners to obtain the representation of their aggregated understanding. The teacher can also compare the over-lapped map with the goal map. Using the overlapped map, the teacher can analyze the trend of learners' understanding in the class, thus making it possible to provide feedback to the learners (Pailai, Wunnasri, Yoshida, Hayashi & Hirashima, 2017; Yoshida, Sugihara, Nino, Shida & Hirashima, 2013).

In this paper, we analyze collaborative learning among learners from the point of individual activities through small-group task based on the KB method. The rest of this paper is organized as follows. Firstly, we present an overview of KBmap. Then, we present and discuss our case study and the data captured from it. We conclude with the results and future research directions.

## 2. Collaborative learning with KBmap in classroom

### *2.1 Goal of lesson*

The goal of the lesson in this study is that, at the end of the course unit, the learners collaboratively organize what they have learned in the unit as shared knowledge in the class. Toward this end, the teacher designs the lesson as a sequence of individual activities, small-group task, and whole-class discussion. First, the students individually organize what they have learned, after which they share it to verify or compensate for a gap in understanding. Finally, the results of the small-group task are shared in the whole-class discussion, and understanding can be achieved based on the fusion of a variety of perspectives.

For coordinating this kind of lesson, it is necessary for the teacher to keenly monitor students' learning in each step, and provide suggestions accordingly. To meet this requirement, the teacher in this study uses the KBmap system to capture the collaborative learning process in the lessons. In addition to enabling teachers to efficiently evaluate students' learning in the form of the concept map, constructing the KBmap also enables learners to organize what they have learned.

Figure 1 shows the concept map made by the teacher, subsequently referred to as the goal map, in this study. The topic considered in the study is the characteristics of Latin America, with emphasis on the relationship among industries, economic development, and deforestation. The teacher assumes that the learners have no knowledge of all the relations, and have a preconceived notion the relationship between development and deforestation is negative. It is expected that after this lesson, the learners will know the correlation of all the industries with both economic development and deforestation, and be able to explain these correlations. Additionally, it is expected that beyond holding a simplistic view of development and deforestation being inharmonious, learners become aware of the dilemma of both concepts. The aim of this lesson is that the students learn by independently and collaboratively integrating the knowledge acquired in previous classes in addition to the teacher's complimentary instruction.

The goal map is decomposed into separate nodes and links, and provided to the students as a kit to compose a concept map representing their understanding. Figure 2 shows the kit provided to the learners in this study. In this lesson, the teacher decomposes only the right part of the goal map to clarify the tasks undertaken by the students. The left part of the goal map represents the geographical features of Latin America, and is not decomposed; it maintains its structure. The left part had been composed by the students in the previous lessons.

On the other hand, the right part represents the correlation between the features of economic growth (development) and deforestation (destruction) . The main task of the students in this lesson is to explore the correlation and represent it on a concept map. In this lesson, students build a concept map representing their thoughts using the kit, and then, construct an accurate map following discussion.

As stated above, the teacher's expectation is that using this concept map, the learners learn the correlation among all the industries and development and deforestation. The KBmap editor becomes a learning material that aids the learners to represent their understanding, and the KBmap analyzer becomes a tool for teachers to capture learners' comprehension during and after class.

Although the KBmap is limited by its closed content, it sufficiently enables the shared understanding of the lesson content, and lays the ground for realizing collaborative knowledge. In this study, the aim is that the students share their understanding of what they learned in the previous class, as the preparation for creating collaborative knowledge (Stahl, 2000). In constructing the KBmap, learners use limited nodes and links provided by the teacher. Even if the learners only assemble a concept map instead of segmenting the source information, Funaoi et al. (2011) demonstrate that constructing the KBmap achieves the same learning effect in relation to the contents in the goal map. This suggests that the KBmap can help learners to express their understanding based on the provided components. Moreover, teachers can utilize the diagnostic results from the KBmap as a formative assessment tool for designing feedback (Yoshida, 2013)(Pailai, 2017).

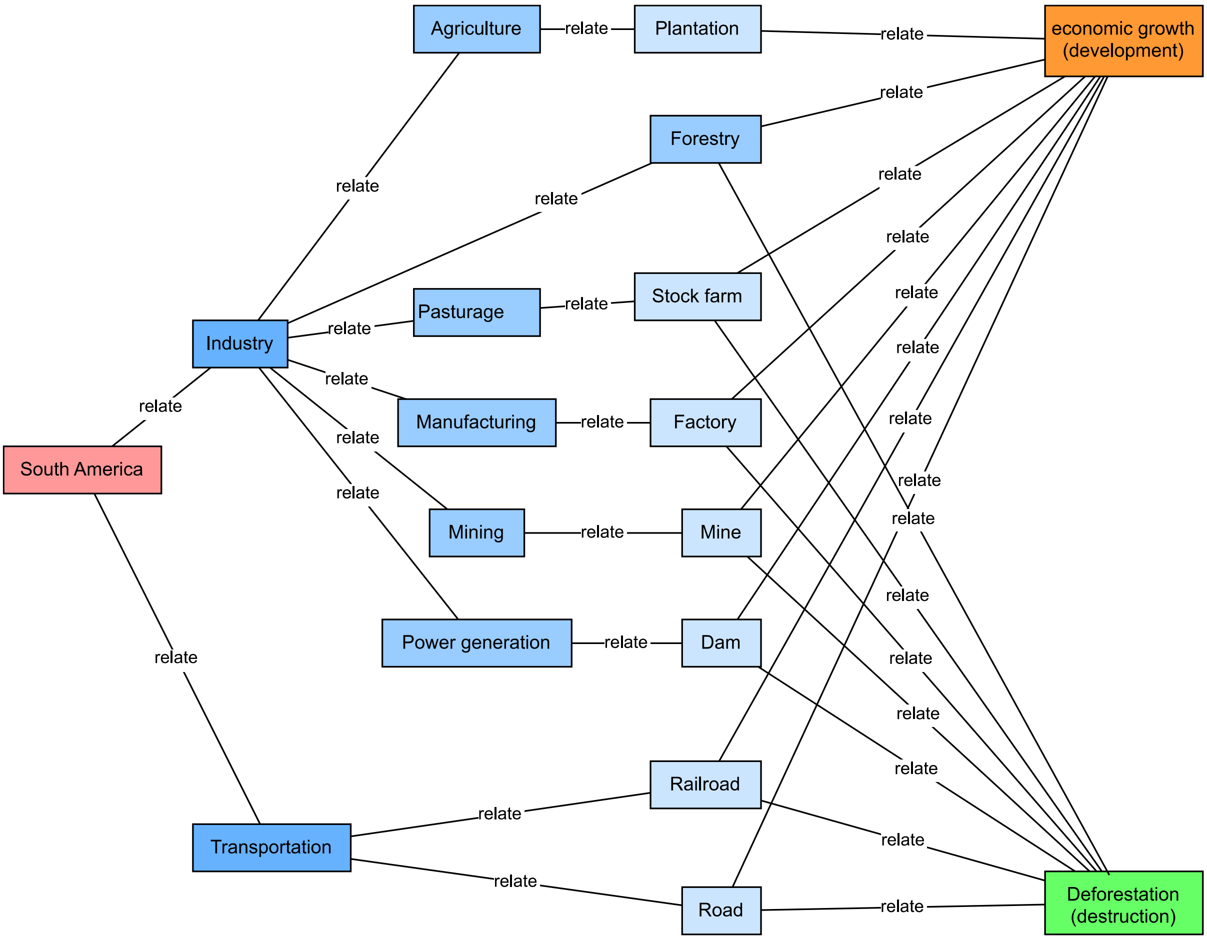


*Figure 1.* Goal map

### 2.2 *KBmap system*

The system for kit-build mapping is called the "KBmap system." It is composed of two client systems, "KBmap editor" and "KBmap analyzer," and the server system, "KBmap DB" [9]. Two types of KBmap editor work on desktop and tablet computers. The KBmap editor on desktop computers is for both teachers and learners. Teachers can create goal maps and kits for learners, and learners can make their map using a kit on the desktop version.

On the other hand, the tablet version is solely for the learners. Figure 2 shows the screenshot. The left side shows a kit that includes separate nodes and links. The right side is the KBmap made from the kit. A key characteristic of the tablet version is its portability. Thus, it can be used not only in computer rooms but also in normal classrooms. In this study, lessons were conducted in a normal classroom using a Wi-Fi network.

The KBmap analyzer works only on web browsers on PCs and tablet computers. The function of the KBmap analyzer is to show the group map that overlays the learner-maps. On this map, the more the number of learners that define a link between particular concepts, the more emphatically the link is displayed. On the window, links that many learners' sets are displayed as thick and high-colored lines; only few sets are displayed as narrow and light-colored lines. In addition to that, the KBanalyzer shows each link made by the learners. With this information, the teacher can identify which links in the goal map are difficult for the learners to identify when they make their maps from a kit (Sugihara, Osada, Nakata, Funaoi & Hirashima, 2012).

The KBmap is applicable to a variety of subjects: science in elementary schools (Hirashima, Yamasaki, Fukuda & Funaoi, 2011; Hirashima, Yamasaki, Fukuda, & Funaoi, 2015), geography in junior high schools (Nomura, 2014), English as a second language (Alkhateeb, Hayashi, & Hirashima, 2015), and university-level social science and computer science (Hayashi & Hirashima, 2014)(Hayashi & Hirashima, 2015).

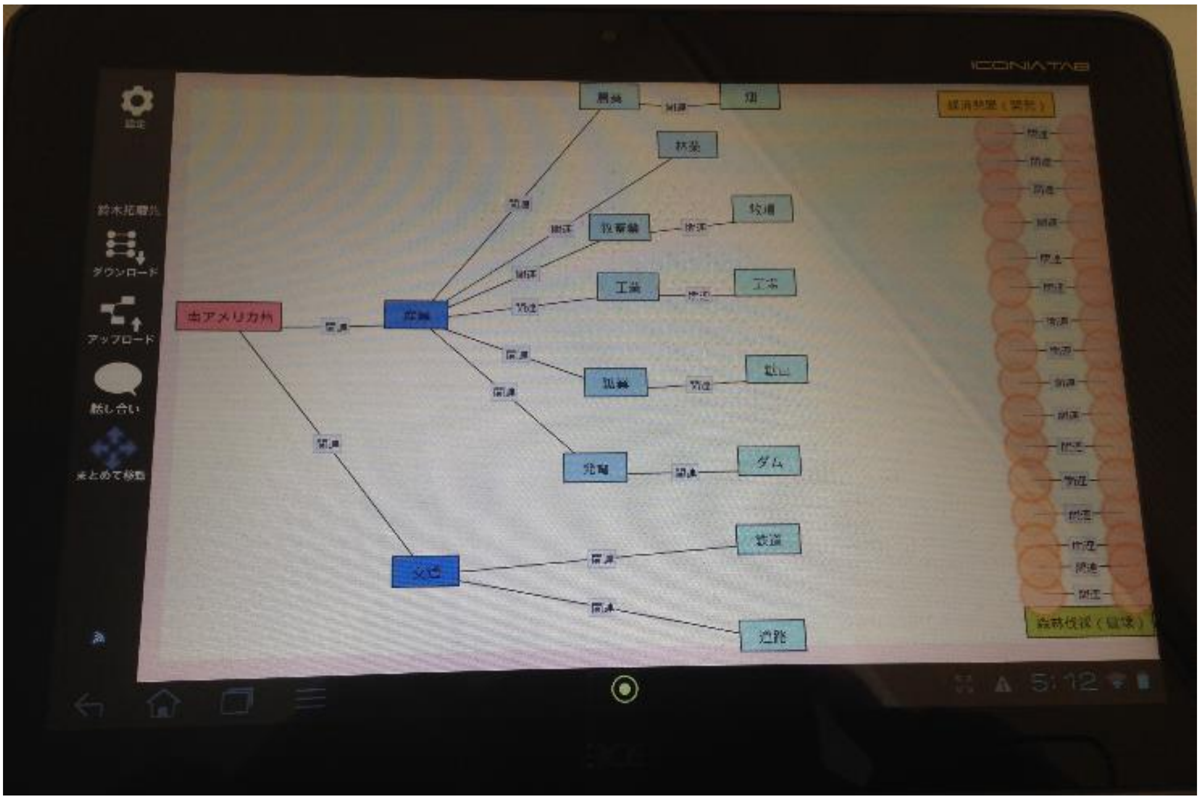

*Figure 2.* Kit made from the goal map

### *2.3 The procedure of the lesson*

In the lessons, students performed the two activities below:

- organize the knowledge acquired from the previous lessons as a concept map from the kit, and
- compare and validate their understanding as represented on the KBmap editor through small-group and whole-class discussion.

Subsequently, the teacher explained the lesson he intended to impart based on the comparison of the goal map and the students' KBmaps. Through this, students were expected to resolve the lapses in comprehension following discussion.

The lessons were composed of the following steps:

#### Teacher reviewed the previous lessons with the students

Using some pictures, the teacher reminded the students of the features of Latin America that were learned in the previous classes. The teacher integrated all the separate lessons from each class in the form of a concept map. In addition to that, the teacher provided some pictures related to these features. This enables the students to have a concrete image of the features.

#### Individuals build concept maps (pre-map)

Using a tablet computer, each student individually completes the concept map representing the relation of the features to economic development and environmental degradation in Latin America within a set time. Here, individual students considered the relation based on what they learned in the previous classes and the pictures on the tablet. Although the teacher had explained some of the relations, he had not emphasized them. Therefore, these were not mere recall tasks.

### Groups build a concept map (collaborative map)

Just after building the pre-maps, without verifying the answers, the students went into small groups of four or five. In each group, the students discussed the correlation between the features of economic development and environmental degradation in Latin America. The goal of the group in this step was to reach a consensus, and build a concept map (collaborative map). Each group built a collaborative map representing the consensus reached from the personal maps of the members.

### Individuals modify their pre-maps (post-map).

After the group map was built, and before it was reviewed by the teacher, students were allowed to revise their maps. The students could modify their thoughts to reflect the group discussion. The purpose of this step was to enable the learners be aware of their change of thought and record the change.

### Whole-class instruction by the teacher (group map)

Finally, the teacher provided the correct answer based on the result of the groups. Although it is desirable for the teacher to explain the correct answer in detail, he simply provided an overview, because of classroom time constraint.

## 3. Data from a case of in-class collaborative learning

We conducted three lessons in three classes in a junior high school in Japan. The participants were 76 first-grade students (12-13 years old). The lessons were conducted in regular classrooms; the usual tasks with paper worksheets were replaced by tasks using the KBmap system on tablet computers. We made no comparison between paper worksheets and tablet computers, because the purpose of this study was not to measure the learning gain but to investigate the effectiveness of the KBmap system for detecting changes in learners' perspectives. The data captured during and after class using the KBmap system are presented in the next subsection.

### *3.1 Group map*

During the classes, the teacher used only the aggregation of the collaborative maps, and was able to identify the commonly misunderstood area. Thus, the whole-class instruction was structured around it. According to our initial plan, the teacher was to use the group maps composed of the individual pre-maps. However, this was a challenge, because of time constraint .

Figure 3 shows the group maps, emphasizing the links over half of the group have failed to set in the collaborative-maps. In the goal map, all the industries are linked to both development and deforestation. Therefore, through missing links, the correlation many of the learners were not aware of could be identified. Based on the group maps, the teacher provided feedback to the students in the whole-class instruction.

As shown in Figure 3, the missing links varied from class to class. Before the class, the teacher assumed that majority of the students could not draw the correlation among the new concepts, railways, and roadways. However, according to the group maps, such prediction is not always accurate. Furthermore, the teacher did not foresee the lack of understanding of various propositions. A significant number of the students had no knowledge of some of the propositions. These propositions are as follows. In Class A, "Forestry is related to economic growth" and "Factory is related to deforestation"; in Class B, "Stock farm is related to economic development" and "Stock farm is related to deforestation"; in Class C, "forestry is related to economic developments" and "Mine is related to deforestation". Thus, after concept mapping, the teacher could focus solely on expatiating on these propositions. After the lessons, the teacher revealed that the approach made it possible to efficiently evaluate the students' understanding. Previous attempts to investigate the thoughts of individual students during group work had required the help of several other teachers, and organizing the result during lessons was a challenge. However, using the proposed method, the teacher was able to efficiently assess the learners' understanding, and structure the lesson around it.

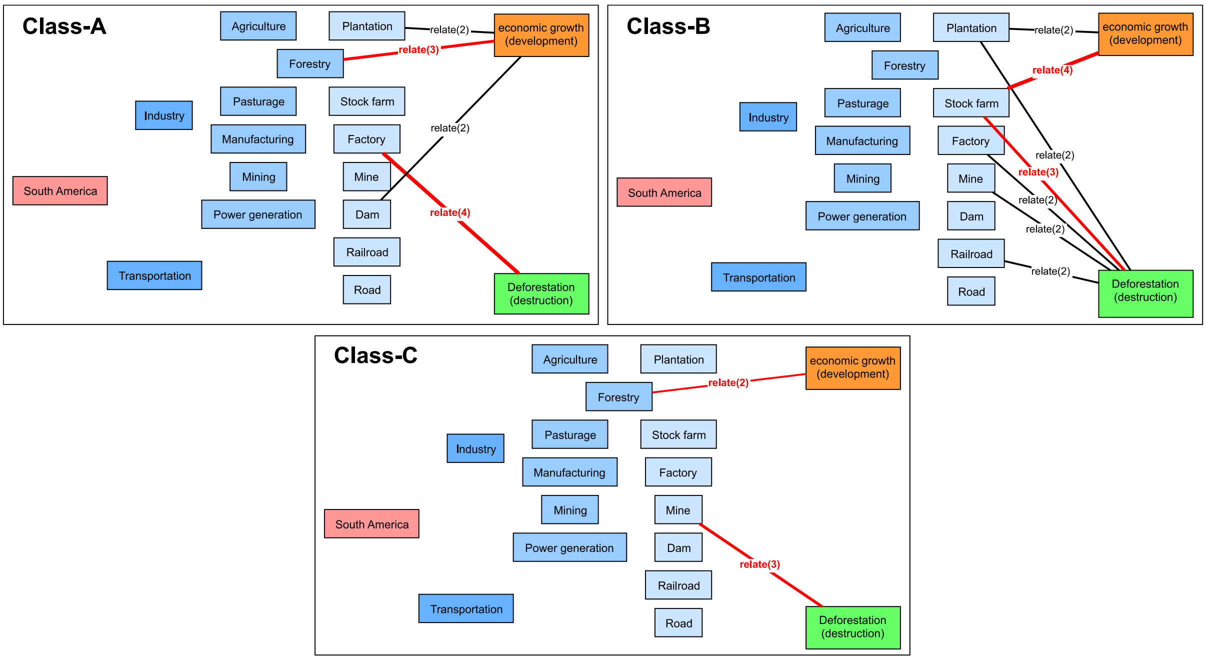


*Figure 3.* Group maps

## *3.2 Change of map score*

Figure 4 and Table 1 show the comparison between the average scores of the pre-maps and the post-maps. The score of the learner's map reveals the degree of similarity between the learner's map and the goal map. It takes a value ranging from 0 to 1. If the score is 1, the learner's map is exactly the same as the goal map. The score is calculated using the following equation:

$$mapscore\ of\ a\ learne's\ map = \frac{the\ number\ of\ the\ same\ propositions\ in\ the\ learner's\ map\ and\ the\ goal\ map}{the\ number\ of\ the\ propositions\ in\ the\ goal\ map}$$

Table 1
*Map Scores*

| | Pre-map | Collaborative-map | Post-map |
|---|---|---|---|
| Class-A | 0.5817 (*SD*=0.2206) | 0.8125 (*SD*=0.1936) | 0.7764 (*SD*=0.1922) |
| Class-B | 0.5885 (*SD*=0.2395) | 0.7708 (*SD*=0.1407) | 0.7839 (*SD*=0.1758) |
| Class-C | 0.6400 (*SD*=0.2226) | 0.8958 (*SD*=0.1164) | 0.8950 (*SD*=0.0967) |

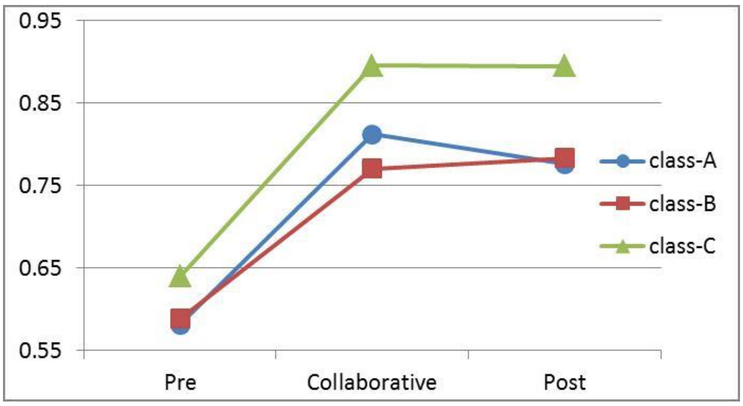


*Figure 4.* Average map scores in three classes

The average scores of the post-maps exceeded those of the pre-maps in every class. Based on the Wilcoxon signed-rank test, the difference is significant (Class A: $n = 26$, $V = 210$, $p < 0.01$; Class B: $n = 24$, $V = 148.5$, $p < 0.01$; Class C: $n = 25$, $V = 253$, $p < 0.01$). This result indicates that creating the KBmap in a group improved the students' understanding.

Furthermore, this study compared the score of the pre-map to the score of the collaborative map using the Wilcoxon rank-sum test. A significant difference was found between the pre-map score and the post-map score in every class (Class A: $n = 26$, $U = 31.5$, $p < 0.05$; Class B: $n = 24$, $U = 34$, $p < 0.01$; Class C: $n = 25$, $U = 34.5$, $p < 0.01$). The scores of the collaborative maps exceeded those of the pre-maps. This finding suggests that the knowledge attained collaboratively was more accurate than the average knowledge attained individually.

Consequently, the closer the pre-map was to the collaborative map, the higher the degree of the similarity among the group members' maps, and because the score of the collaborative map exceeded that of the pre-map, the students' knowledge improved.

### *3.3 Types of map change following small-group discussion*

Figure 5 shows the classification of the group according to hierarchical cluster analysis. There are four types of group: advanced and improvement, follow-up and raise, collective and improved, and collective and raise.

Cluster 1 is "advanced and improved". Here, the scores of the collaborative maps exceeded that of the maximum score of the pre-maps in the group. This implies that the collaborative map was not a mere fusion of the pre-maps. Rather, the students, as a group, successfully integrated their pre-maps, and possibly found a new relation. Furthermore, the average, maximum, and minimum score of the post-maps exceed those of the pre-maps, thus demonstrating that the members' understanding is generally improved through the small-group discussion.

Cluster 2 is "follow-up and raised". Here, the scores of the collaborative maps are the same as the maximum score of the pre-maps. Each group in this cluster adopts the maximum score of the pre-maps as their collaborative map. Finally, although the average and minimum scores of the post-maps of the groups increased, the maximum score remained the same. Specifically, in Groups B1, B4, and C3, all the members' scores following the post-maps are equal to the collaborative map. In this cluster, it was possible for some students to improve their understanding through the small-group discussion.

Cluster 3 is "collective and improved". This cluster is similar to Cluster 1. However, the scores of the collaborative maps were lower than the maximum score of the pre-maps. Although it was not possible to fully collate the acquired knowledge of the group members, they could all achieve improved comprehension.

Cluster 4 is "collective and raised". This cluster is similar to Cluster 3, as the scores of the collaborative maps were not the same as the maximum score of the pre-maps in the group. Although the average scores of these groups' post-maps increased, the maximum score and even the minimum scores remained consistent in several groups. In this cluster, some students were able to improve their understanding through the small-group discussion.

The characteristics of these clusters as stated above depend on the membership of the group. For example, Groups B1, B2, C3, and C6 consisted of individual learners that earned full marks in the pre-map scoring. Thus, these scores could not be exceeded in the post-test. It was however possible for learners to obtain a lower score at the post-map. Their score is not changed, and the others adopt some answer to him/her.

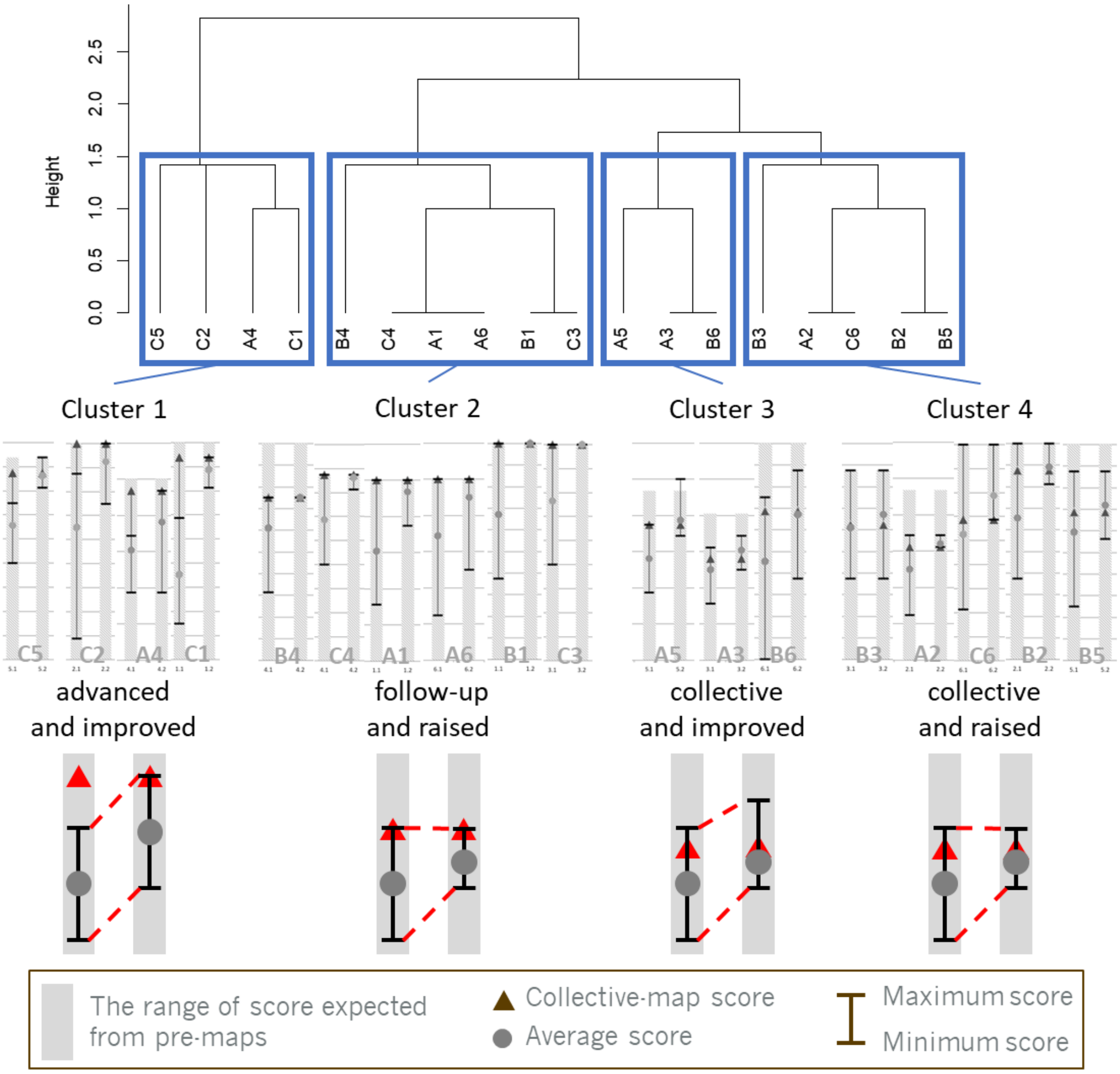


*Figure 5.* Clusters of groups

## 4. Conclusion

This paper presents the result of a case study of the implementation and data analysis of in-class collaborative learning using the KBmap. The KBmap automatically evaluates the concept maps of individual learners based on the teacher's goal map. It is a potential solution to the challenges of implementing concept mapping in the classroom. The data captured using the KBmap system, such as correctness and similarity, can be used during and after classes.

Such data can be used for formative and summative evaluation. The teacher in this study was able to qualitatively assess the students' understanding, rather than quantitatively, and provide feedback accordingly. Typically, it is difficult for teachers to monitor the learning and comprehension process during collaborative learning. The conventional methods of acquiring this knowledge include allowing the students to give a presentation, or carefully scrutinizing their conversation. Although the KBmap provides a kit for concept mapping and delineates the bounds of the map, the small-group and whole-class discussion is not limited to the boundary. In other words, the KBmap itself is a close-ended learning environment. However, depending on implementation and the activities, a class using the KBmap can be open-ended. For example, in this study, there are many reasons to identify the correlation between industry and development or deforestation. In such a case, the KBmap can assess students' understandings at a minimum level where the teacher wants to share with them. Naturally, the teacher allows for the diversity of perspectives depending on the topics; such can be covered through discussion or other methods. This study demonstrates the possibility of capturing and analyzing data during in-class collaborative learning, the consequent realization of formative and summative evaluation, and the corresponding feedback during and after class. In the future, we aim to clarify the range of capture and analysis of collaborative learning with the KBmap, and to develop functions for evaluation and feedback by teachers.

## References


Alkhateeb, M., Hayashi, Y., and Hirashima, T. (2015) Comparison between Kit-Build and Scratch-Build concept mapping methods in supporting EFL reading comprehension. Journal of Information and Systems in Education, 14(1), 13–27.

Dillenbourg, P. and Jermann, P. (2010) Technology for Classroom Orchestration, New Science of Learning, pp. 525–552, Springer, New York.

Dillenbourg, P. (2013). Design for classroom orchestration. Computers & Education, 69, 485–492

Hayashi, Y. and Hirashima, T. (2014) Kit-Build concept mapping for being aware of the gap of exchanged information in collaborative reading of the literature. Proc. Int. Conf. on Human Interface and the Management of Information, 31–41.

Hayashi, Y. and Hirashima, T. (2015) Analysis of the relationship between metacognitive ability and learning activity with Kit-Build concept map. Proc. Int. Conf. on Human Interface and the Management of Information, 304–312.

Herl, H. E., O'Neil, H. F. Jr., Chunga, G.K.W.K., & Schacter, J. (1999). Reliability and validity of a computer-based knowledge mapping system to measure content understanding. Comput. Hum. Behav., 15, 315–333.

Hirashima, T., Yamasaki, K., Fukuda, H., and Funaoi, H. (2011) Kit-Build concept map for automatic diagnosis. Proc. of 15th Conf. on Artificial Intelligence in Education, 466–468.

Hirashima, T., Yamasaki, K., Fukuda, H., and Funaoi, H. (2015) Framework of Kit-Build concept map for automatic diagnosis and its preliminary use. RPTEL, 10(1), 1–21.

Hoppe, H.U. (2017) Computational methods for the analysis of learning and knowledge building communities, Handbook of Learning Analytics First Edition, https://solaresearch.org/hla-17/hla17-chapter2/

Martinez-Maldonado, R., Clayphan, A., Kay, J. and Yacef, K. (2014) Towards providing notifications to enhance teacher's awareness in the classroom. ITS, 510–515.

Matsuzawa, Y., Oshima, J., Oshima, R., Niihara, Y., Sakai, S., (2011) KBDeX: A Platform for Exploring Discourse in Collaborative Learning Procedia - Social and Behavioral Sciences, Vol. 26, pp. 198–207.

Nomura, T., Hayashi, Y., Suzuki, T. & Hirashima, T. (2014) Knowledge propagation in practical use of Kit-Build concept map system in classroom group work for knowledge sharing. ICCE2014 Workshop Proceedings. pp. 463–472.

Novak, J. D., & Cañas, A. J. (2006). The theory underlying concept maps and how to construct them. IHMC, 1.

Oshima, J., Oshima, R., Matsuzawa, Y. (2012) Knowledge Building Discourse Explorer: a social network analysis application for knowledge building discourse, Educational Technology Research and Development, Volume 60, Issue 5, pp. 903–921, 2012.

Pailai, J., Wunnasri, W., Yoshida, K., Hayashi, Y., and Hirashima, T. (2017) The practical use of Kit-Build concept map on formative assessment. RPTEL, 12:20. https://doi.org/10.1186/s41039-017-0060-x.

Ruiz-Primo, M.A. (2004). Examining Concept Maps as an Assessment Tool. Proc. of the First Int. Conference on Concept Mapping, Pamplona, Spain. Available: http://cmc.ihmc.us/papers/cmc2004-036.pdf

Stahl, G. (2000). A model of collaborative knowledge-building. In B. Fishman & S. O'Connor-Divelbiss (Eds.), Fourth International Conference of the Learning Sciences, pp. 70–77), Mahwah, NJ: Erlbaum.

Sugihara, K., Osada, T., Nakata, S., Funaoi, H., and Hirashima, T. (2012) Experimental evaluation of Kit-Build concept map for science classes in an elementary school. Proc. ICCE 2012, 17–24.

Tergan S-O. (2005). Digital concept maps for managing knowledge and information. In Knowledge and Information Visualization, Sigmar-Olaf Tergan and Tanja Keller (Eds.). Springer-Verlag, Berlin, Heidelberg 185–204.

Yamasaki, K., Fukuda, H., Hirashima, T., & Funaoi, H. (2010). Kit-build concept map and its preliminary evaluation. In Proc. of ICCE, 290–294.

Yoshida, K., Sugihara, K., Nino, Y., Shida, M., and Hirashima, T. (2013) Practical use of Kit-Build concept map system for formative assessment of learners' comprehension in a lecture. Proc. ICCE 2013, 906–915.