Experimental Evaluation of Kit-Build Concept Map for Science Classes in an Elementary School

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Abstract: We have already proposed Kit-Build Concept Map (we call it as "KB map") that is a framework to realize automatic diagnosis of concept maps built by learners and to give feedback to their errors in the maps. In this paper, we report an experimental evaluation of KB map in science learning in an elementary school. Two classes of fourth grade students in an elementary school attended the experiment. "Waxing and Waning of the Moon" in science class was the topic of this experiment. The results suggested that the diagnosis and feedback with the KB map has positive effect to improve learner's understanding of this topic.

Keywords: Kit-Build, Concept Map, Automatic Diagnosis, Goal Map, Learner Map, Group Map, Segmentation and Construction Tasks

Introduction

Many investigations have reported that a concept map is a promising tool to promote learners learning effectively [1-6]. Automatic diagnosis of concept maps built by learners is one of the most important issues to realize useful interaction between learners and their teacher. We have already proposed Kit-Build Concept Map (KB map) as a framework to promote interaction between them based on automatic diagnosis of concept maps [7,8]. This paper reports the results of practical use of KB map for science learning in an elementary school.

In KB map, the task to make a concept map is divided into two sub-tasks: 1) "segmentation task" where parts of the concept map are extracted and 2) "structuring task" where the extracted parts (kit) are integrated into a map. In the framework of KB map, an ideal concept map (goal map) is prepared by a teacher or an expert as the goal of his/her lecture, and parts are generated by decomposing the goal map. The parts are provided to learners, and then the learners build concept maps (learner maps) by connecting the parts. Since the same parts are used both in the goal map and learner maps, it is easy to compare them and detect their differences. The differences from the goal map are errors in the learner map. This detection of the differences is the automatic diagnosis of KB map. Besides, by overlaying several learner maps of a group, a "group map" that expresses the understanding

of the group is generated. By comparing the group map with the goal map, the group map can be also diagnosed.

Several researchers have tackled the problem of automatically diagnosing concept maps and interaction between teachers and learners through the concept maps. Basic approach to realize the diagnosis is to compare the learner's and the teacher's concept maps. Some of the investigations have addressed the automatic diagnosis and paid special attention to handle the cases where learners have misspelled a label of a concept or they have used a synonym or a related concept to the appropriate one, based on techniques of natural language processing and knowledge based reasoning [4, 5]. Betty's Brain [6] has ability to simulate a map built by a learner and the results of simulation promote the learner to improve the map. Although these researches have advance diagnosis abilities of concept maps, it is necessary to prepare knowledge base or simulation function for a subject domain. Such preparation is usually very difficult for usual teachers. Therefore, it is not easy for teachers to use the concept maps with such advance diagnosis. Then, the notations of the concept maps are usually complex because it is necessary to describe the map precisely in order to realize automatic diagnosis. Therefore, they often require high ability for learners.

KBmap is a kind of simplified concept map for a teacher, learners and a system. A teacher is required to describe a map that is composed of nodes and links with labels as the goal of his/her teaching to a class. The teacher is allowed to decide the labels of nodes and links depending on his/her teaching session. This means that the teacher is not required to keep specific notation and is allowed to use his/her word. Therefore, interpretation of the goal map depends on specific teaching/learning context. Although it is not easy to interpret the map in general, it can be expected that it is possible and useful for learners who learned in the specific context. As for diagnosis of a system, although meanings of the differences detected by comparing the goal map and the learner maps cannot be interpreted, each difference itself indicates a defect of his/her understandings and it is possible for the teacher and learners to find the meaning of the difference because they share the same context.

In order to examine whether KBmap works as expected, we used KBmap practically in science learning in an elementary school. The learning topic is "waxing and waning of the Moon" and subjects are fourth grade students in two classes. Through this practical use, we have confirmed that (1) teachers were able to build the goal map themselves (2) learners were able to build their map by using provided parts and they thought the building activity was useful for learning, and (3) feedback for learners by means of the group map was useful to improve their understanding.

1. KBmap System for "Waxing and Waning Moon"

In this section, we introduce implementation of KBmap system for subjects of "waxing and waning Moon".

1.1 KBmap System

We have already developed a system based on the framework explained in the previous section. This system is called as "KBmap System". It is a web application with two client systems: "KBmap Editor" and "KBmap Analyzer", and a server system: "KBmap DB". KBmap Editor provides an environment to make a goal map, a kit, and a learner map. This system has been implemented by Java (version 1.6). KBmap Analyzer has functions to gather learner maps online, generate a group map and diagnose the maps. This system has implemented by Flash and supports version Flash Player 10. KBmap DB has a function to store and share maps. This system was developed by Ruby (version 1.8.7) on Rails (version

1.2.3) and MySQL (version 5.1.30). Flow of teaching/learning with KBmap System is explained in the next section.

1.2 Flow of Teaching/learning with KBmap System

The flow of teaching/learning with KB map is composed of following four phases: (1) goal map building by a teacher as a part of preparation of learning material, (2) teaching with the learning material, (3) learner map building by learners as reflection of their learning, (4) diagnosis of learner maps by the teacher, and (4) feedback and complementary teaching to learners based on the results diagnosis. In the goal map building, a teacher or an author of a learning material is required to build a goal map as an ideal concept map that learners would make after their learning activity. Figure 1 shows a typical figure that is used to teach the cycle of “waxing and waning Moon”. Figure 2 shows the goal map that was made by a teacher in the practical use of KB map reported in this paper. In this map, "Waxing Moon" or "New Moon" corresponds to a node word and "Set" corresponds to a link word. A set of components (it is called "kit") is generated by decomposing the goal map, as shown in Figure 3. In the phase of leaner map building, a learner is required to build a concept map (learner map) with the kit. Figure 4 shows an example of learner map building by KBmap Editor. Because a map is composed by connecting links between nodes, all errors are detected as mistakes in link connection. In Figure 4, “rising” is not used in the learner map. We call this error as “leaving link”. Since “setting” link from “waxing moon” to “evening” in the learner map does not exist in the goal map, this error is called as “excessive link”. Then, “crossing the meridian” link from “waxing moon” to “evening”. We call them as “lacking link”.

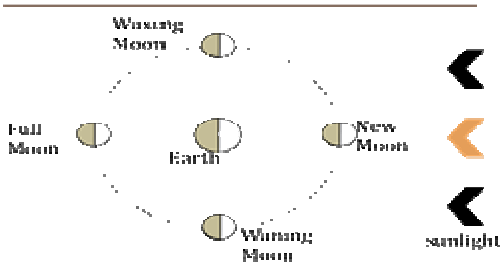

Figure 1: Waxing and Waning of the Moon

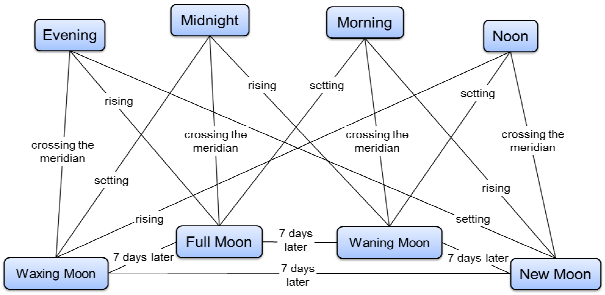

Figure 2: Goal Map

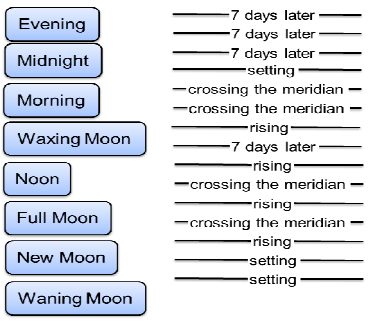

Figure 3: Kit of the Goal

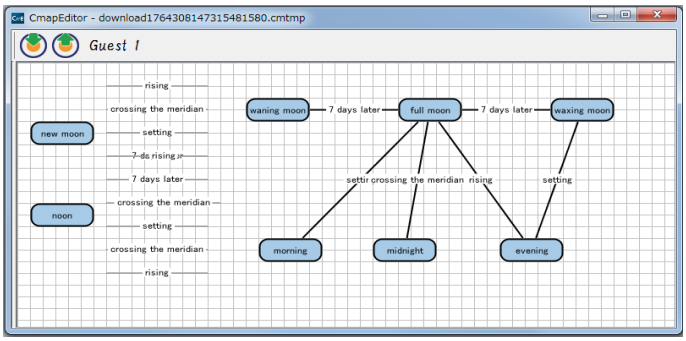

Figure 4: Learner Map building by KBmap

By overlaying several learner maps, it is easily to generate a group map describing understanding of a learner group. A link in the group map has a "overlaid degree" that is a ratio of learner maps including the link. By comparing the group map with the goal map, the weak points in understanding of the topic of the group are detected. Figure 5 shows group

map where a link connected by many learners is marked with bold line. A thin line means that very few learner maps include the link. Thickness of link changes gradually by the number of students that connected the link. By comparing the group map with the goal map, “group difference map” is generated as show in Figure 6. In the difference group map, a solid link expresses a lacking link and a broken link expresses an excessive link or a leaving link. In this difference group map, usually many errors are detected. Therefore, KB map system has ability to arrange the overlaid degree for visualization of errors in the group map. In the case of Figure 6, there are four error links with high overlaid degree are shown. Bold solid link “rising” means that many learners couldn’t connect it to any nodes.

Diagnosis of learner maps is carried out as generation of the group map and group difference maps in the framework of KB map. Several types of feedback are able to realize based on the diagnosis. In the experimental use of KB map in this paper, a teacher detected high frequent mistakes from a group difference map and gave learners feedback to remedy the mistakes.

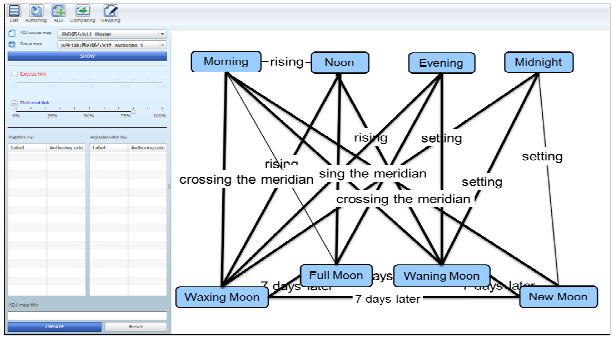

Figure 5: Group Map.

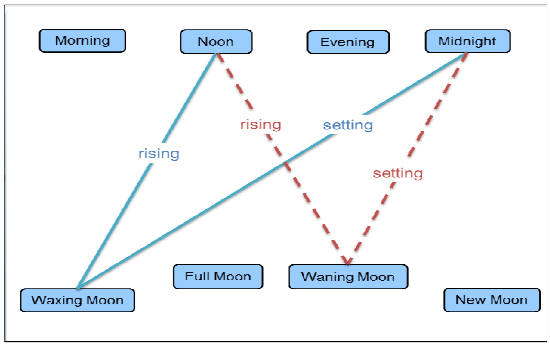

Figure 6: Group Difference Map

2. Experimental Use

2.1 Outline of the use

In this use, seventy-two 4th grade students (9 or 10 years old) in two classes attended. All of them had taken three lectures (45 minutes per a lecture) of “waxing and waning of the Moon” before two weeks of the use of KBmap system. A day before the use, they took a test for measuring their understanding about the topic for thirty minutes (this is a pre-test). At the first use of KB map, they build their respective maps of “waxing and waning of the Moon” with KBmap system for thirty minutes in a class after the introduction of the operation of KB map. The map build in this class in called “first map”. A week later of the use, a teacher in charge of the two classes gave a feedback lecture. For one class, the teacher gave feedback with KB map (details are explained in the next subsection). In contrast, for another class, the teacher gave feedback with the results of the pre-test with explanation of the questions and errors. This is a typical feedback for exercises or examinations in a usual class. Here, we call the former class “map feedback class” and the latter class “usual feedback class”. Then, a few days later, all of them built the maps of “waxing and waning of the Moon” again with KBmap system. This map is called “second map”. In the same time, they answered questionnaires. A post-test that was the same one with the pre-test was carried out two weeks later of the map use. All of the above lectures were conducted the teacher in charge of the two classes. In the classes of the use of KBmap system, four or five assistants (including authors) participated in the classes to help learners to use the system. In this use, another teacher also attended as an observer. The two teachers were science teachers who took charge of all science lectures of the elementary school.

2.2 Maps Built in the Use

Figure 2 shows a goal map prepared by the teacher. This goal map was prepared by a teacher in charge of the subjects and another science teacher accepted it. Although the responsible teacher said to prepare the goal map was not easy. he also commented that the preparation of the goal map was reasonable task as a part of preparation of learning materials. Moreover, the teacher made the goal map commented that to make the map was useful to arrange the learning material. Then, another teacher commented that to check the goal map was useful to understand the lecture. Figure 4 shows examples of learner map. A group map is shown in Figure 5. In the feedback lecture with KB map, the teacher used a group difference map as shown in Figure 6. Because the group difference map itself is too complex to show learners directly, gradual visualization function is used. At first, the teacher took on the highest ratio link and showed the learners only it. Then, the teacher requested the learners to think about whether the link was correct or not. In this case, "rising" link between "midnight" and "waning moon" was the excess link with the highest frequency. After gathering several opinions from learners, the teacher explained correct answer. Then, the teacher moved to the second excess link. Figure 6 shows in a snapshot of this gradual visualization of the group difference map. In this figure, four links with the highest ratio are shown. They are as follows: "waxing moon-rises-noon", "waxing moon–sets–midnight", "waning moon-rises-noon", "waning moon–sets–midnight". As the ratio, more than 20% learners wrongly connected the four links.

2.3 Analysis of Map Scores and Test Scores

We have categorized learners into "map feedback" group and "usual feedback" group. The map scores were obtained before and after the feedback lecture. Former one is the "first map score" and the latter one is the "second map score". The learners are also categorized into "high score" group and "low score" group by the average score of the first maps. The test scores were obtained as the pre-test and post-test. As for the test scores, the learners are also categorized into "high score" group and "low score" group by the average score of the pre-test. The test was composed of eleven questions that could not be solved only by the information explicitly described in the goal map. The test is a little advanced but not special one. Similar type of test is often used to confirm understanding of "waxing and waning the Moon" in elementary schools.

2.3.1 Map Scores

A score of each learner map is calculated by counting correctly connected links by comparing the goal map. In this paper, the score is expressed as ratio of correct links, so full mark is "1". Because of a few absent learners in the map building classes, 67 pairs of maps scores (first & second) were used in this analysis. Their average scores are shown in Table 1. Average first map scores of the whole class is 0.65 (SD = 0.29). Changes of map scores in each category of learners between the first map and the second map are shown in Figure 7.

Table 1: Map Scores

	First Map Score	Second Map Score
Map Feedback (n = 35)	0.71(SD = 0.27)	0.89 (0.16)
High Score (n = 21)	0.89 (0.10)	0.93 (0.12)
Low Score (n = 14)	0.43 (0.19)	0.82 (0.18)
Usual Feedback (n = 32)	0.60 (0.30)	0.67 (0.30)
High Score (n = 12)	0.94 (0.07)	0.90 (0.14)
Low Score (n = 20)	0.39 (0.16)	0.53 (0.29)

The results of map scores were analyzed with a three-way 2 (map feedback or usual feedback) x 2 (high score group or low score group) x 2 (first map or second map) mixed ANOVA, multiple comparison was made using Ryan's method. As the results, the secondary interaction between map/usual, high/low and first/second was marginally significant ($F(1,63) = 3.471$, $p < 0.1$). As for the simple-simple main effect of "map/usual feedback" factor, there is a significant difference in the maps scores in "low score & second map" ($F(1,126)=21.9$, $p < 0.001$) although there are not significant differences in "high score" and "low score & first map". As for the simple-simple main effect of "low/high score" factor, there are significant differences in "usual feedback" and "map feedback & first map" (for all of them, $p < 0.001$), and there is marginal difference in "map feedback & second map" ($p = < 0.1$). As for the simple-simple main effect of "first/second map" factor, there are significant differences in "low score" (for all of them, $p < 0.001$), and then, there are no significant differences in "high score".

As the results in statistically, the low score learners both in "map feedback" and "usual feedback" improved their maps although the high score learners didn't. Besides, "map feedback" was more effective than "usual feedback" to improve their map scores. Effect size between the first map score and the second map score in "map feedback & low score" condition is $d = 3.05$ (extra-large) and effect size between the first map score and the second map score in "usual feedback & low score" is $d = 0.87$(large). Then, the effect size between the second map scores of "map feedback & low score" and "usual feedback & low score" is $d = 1.74$ (extra-large).

2.3.2 Test Scores

The pre-test and post-test are the same one and its full mark is eleven. The average scores and standard deviations are shown in Table 2. Because of a few absent learners in the map building classes, 71 pairs of test scores (pre and post) were used in this analysis. Average of pre-test score is 6.3 (*SD* = 2.4). Changes of test scores in each category of learners between the pre-test and post-test are shown in Figure 8.

Table 2: Test Scores

	Pre-Test	Post-Test
Map Feedback (*n* = 35)	5.94 (*SD* = 2.12)	9.00 (2.12)
High Score (*n* = 12)	8.32 (0.85)	8.25 (2.55)
Low Score (*n* = 23)	4.70 (1.27)	9.39 (1.74)
Usual Feedback (*n* = 36)	6.7 (2.7)	7.3 (2.3)
High Score (*n* = 22)	8.41 (1.40)	8.41 (1.83)
Low Score (*n* = 14)	4.00 (1.77)	5.43 (1.72)

The results of map scores were analyzed with a three-way 2 (map feedback or usual feedback) x 2 (high score group or low score group) x 2 (pre-test score or post-test score) mixed ANOVA, multiple comparison was made using Ryan's method. As the results, the secondary interaction between map/usual, high/low and pre/post was significant ($F(1,67) = 11.379$, $p < 0.01$). As for the simple-simple main effect of "map/usual feedback" factor, there is a significant difference in the test scores in "map feedback & low score" ($F(1,134)=43.68$, $p < 0.001$) although there are not significant differences in "usual feedback" and "map feedback & high score". As for the simple-simple main effect of "low/high score" factor, there are significant differences in "usual feedback" and "map feedback & pre-test" (for all of them, $p < 0.001$), and there is marginal difference in "map feedback & post-test" ($p < 0.1$). As for the simple-simple main effect of "pre/post test" factor, there are significant differences in "map feedback & low score" ($p < 0.001$) and

"usual feedback and low score" ($p < 0.01$). Then, there are no significant differences in "high score".

As the results, the low score learners both in "map feedback" and "usual feedback" improved their test scores although high score learner didn't. Besides, "map feedback" was more effective than "usual feedback" to improve their test score. Effect size between the pre-test score and the post-test score in "map feedback & low score" condition is $d = 3.09$ (extra-large) and effect size between the pre-test score and the post-test score in "usual feedback & low score" condition is $d = 0.82$(large). Then, the effect size between the post-test scores of "map feedback & low score" and "usual feedback & low score" is $d = 3.06$ (extra-large).

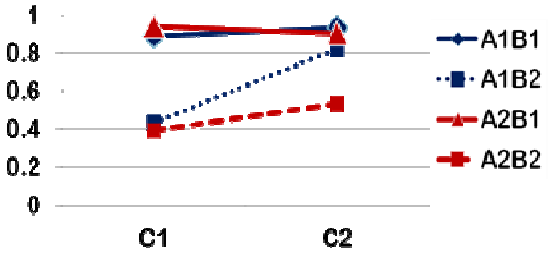

Figure 7: Map Scores

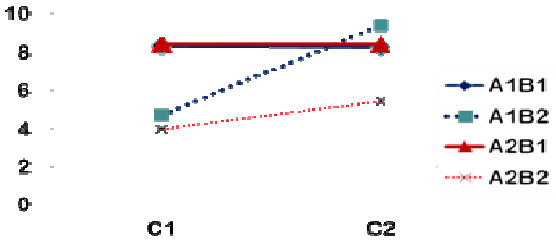

Figure 8: Test Scores

{A1: Map feedback, A2: Usual feedback, B1: High score, B2: Low score, C1: First/Pre, C2: Second/ Pre}

2.3.3 Correlation between the Map and Test Scores.

In order to evaluate the relation between the map scores and the test scores, we carried out Pearson correlation test on 137 pairs of "first map score & pre-test score" or "second map score & post-test score". As the results, there is a statistically significant positive correlation ($r = 0.45$, $p < 0.001$).

2.4 Questionnaires

Table 3 shows the results of a questionnaire for learners. As a result, most of the students agreed that map building is a useful and enjoyable.

Table 3: Results of Questionnaires for Learners

	4	3	2	1
(1) Did you enjoy map building?	65	6	0	0
(2) Was map building useful to learn the Moon?	55	15	1	0
(3) Do you like to use the map for other subjects	63	8	0	0

4 = strong agree, 3 = agree, 2 = disagree, 1 = strong disagree

Table 4 shows the results of a questionnaire for the two science teachers. One is a teacher in charge of the two classes, and the other attended all map building classes as an observer. The results of the analysis were shared before to answer this questionnaire. As a result, the teachers accepted KB map as a useful tool for learning.

Table 4: Results of Questionnaires for Teachers

	4	3	2	1
(1) KB Map Building was useful for learning	2	0	0	0
(2) Prepared Kit positively effect for learning	1	1	0	0
(3) Map feedback is more useful to correct mistakes than usual feedback	2	0	0	0

(4) Map feedback is more useful to motive learners than usual feedback	1	1	0	0
(5) KB map is better than scratch-build concept map in the learning of the Moon.	2	0	0	0

4 = strong agree, 3 = agree, 2 = disagree, 1 = strong disagree

2.5 Consideration

The KB map visualized basic knowledge of the learning topic and all parts were taught in the lecture explicitly. Therefore, building the map would be a reasonable and promising activity to confirm what the learners learned by themselves. This would be a reason that KB map was accepted for most of the learners and teachers as useful learning tool. In the map feedback, errors of learners were indicated in the map. Because map expression is near to learner's inner knowledge expression, the indication would be more direct one and promote learner's knowledge correction. Because the learners of the low score group received more indications of their errors, they could improve their knowledge more than the learners of high score group.

As for high score learners who could not improve their scores, the two teachers has guessed that KB map would give positive effect for their understanding even though it couldn't be measured. To find a method to measure the effect for high score learners is one of the most important issues for our research group.

3. Conclusion

Through this experimental use, we have confirmed that (1) teachers could build the goal map following their teaching, (2) the learners could build KB maps, (3) the learners and teachers accepted KB map as a useful tool for learning, and (4) diagnosis and feedback with KB map were effective to support the learning. Based on these results, we have judged that KB map worked as expected in this learning topics. Because the two teachers also have accepted the usefulness of KBmap, we are collaboratively working together about KB map in order to extend the target domain, find convenient & effective way to use the results of diagnosis of learner maps, and investigate the details of the learning process with KB map.

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