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Reconstructional concept map: automatic Assessment and reciprocal reconstruction

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In this paper, Kit-Build concept map (KB map) is introduced as a reconstruction type of a concept map. In the use of KB map, a learner is requested to build a concept map by using provided components, that is, nodes and links with labels. The set of components (kit) is generated by decomposing a concept map that is originally constructed by a teacher (in teaching-learning) or by a partner (in mutual understanding in collaboration). Because KB map requires a learner to reconstruct the original concept map made by another, KB map building is a promising activity to promote a learner to understand the other's understanding. In KB map, a reconstructed map can be directly compared with the original map and their differences can be detected exactly. Because several maps reconstructed from the same kit can be also laid over each other, a map expressing group understanding is generated as the result of the overlapping. These automatic functions are used in collaborative learning situation to detect differences of the participants' understanding. This paper describes a framework of KB map, practical uses in classrooms, the validity of automatic assessment of KB map, and reciprocal kit-building as a mutual reconstruction of KB map in a collaborative situation.

Keywords: *Reconstructional Concept Map, Kit-Build, Automatic Assessment, Reciprocal Kit-Building*

INTRODUCTION

Concept map is an expression of conceptual understanding via connections between concepts. In an educational context, the concept map is a widely used tool for learning and assessment (Novak 1984; Watson, 2016; Whitelock, 2020). Building styles of a concept map can be categorized into (1) open-ended style and (2) closed-ended style (Herl, 1999; Taricani 2006; Schwendimann, 2016; Cañas, 2016). In the open-ended style, a learner is allowed to use any concepts and linking words in his/her concept map. In contrast, in the closed-ended style, a learner is requested to use only the concepts and linking words provided beforehand. Although many investigators refer to the open-ended style as a standard one from the viewpoint of capturing a learner's knowledge structure, realizating the automatic assessment in the open-ended style is more difficult than in the closed-ended.

In Kit-Build concept map (KB map), a learner is requested to build a concept map by using provided components, which are generated by decomposing the original concept map (Hirashima 2015; Grimaldi, 2015; Won, 2017) . Therefore, the KB map is also a kind of closed-ended building style concept map. It is, then, a more restricted building style in which all components (nodes (concepts) and links(linking words) come from the original concept map. A learner is requested to reconstruct the original map. This concept map building would not be fit for capturing a learner's knowledge structure itself, but it is a promising method to capture how the learner understands what the teacher was trying to convey through a lecture or learning material. Therefore, KB map is fit as an assessment and learning task for a lecture or for reading comprehension. KB map requests a learner to reconstruct the original map by using provided components. This building style is called "reconstruction style" as a kind of closed-ended building style and such a concept map is called a "reconstructional concept map". Table 1 shows a categorization of building style of a concept map in this research. KB map is a framework to realize the reconstructional concept map, and KB map system is an implementation of the KB map practically. This paper describes a framework of KB map and KB map system, practical uses in classrooms, the validity of automatic assessment of KB map, and reciprocal kit-building as a mutual reconstruction of KB map in collaborative situations.

FRAMEWORK OF KIT-BUILD CONCEPT MAP

Figure 1 shows a flow of a practical use of kit-building concept map composed of four main phases: (1) teacher map building by teacher or expert, (2) kit generated by decomposing the teacher map, (3) learner map building with the kit by a learner, (4) assessment of learner map by comparing with the teacher map. A learner map is (re)constructed by using the same components with the teacher map. Therefore, possible locations that a link can be set are the same with the teacher map and the learner maps because they are composed of the same nodes. By using the characteristics of the reconstructional concept map, it is possible to generate (a) difference map and (b) group map. A difference map is generated by comparing a learner map with the teacher map. An example of the difference map is shown in Figure 1 at the phase of assessment by comparison. This difference map is generated by comparing the learner map

with the teacher map shown in Figure 1. In the learner map in Figure 1, both "relate-to link between Sugar and Sucrose" and "is-made-up-of link between Sucrose and Fructose" are lacking, and then, both "is-made-up-of link between Sugar and Fructose" and "unconnected relate-to link" are excess. The difference map composed of the lacking and excess components is shown in the fourth phase in Figure 1. The learner map in Figure 2 is scored 0.75 (=3/4).

A group map is generated by overlapping several learner maps. By overlapping the teacher map and the learner map in Figure 1 and another learner map shown in Figure 2, a group map shown in Figure 3 are generated. It visualizes that "is-made-up-of link between Sucrose and Fructose" is a weak point of the group. In the group map, the number after the link label is the number of maps that include the links. It is possible to generate a difference map between a group map and a teacher map. These difference maps are useful in the visualization of assessment of learners' understanding and are often directly used for feedback for learners.

KB MAP SYSTEM AND PRACTICAL USES IN CLASSROOM

KB map system has been already implemented with the configuration shown in Figure 4. It is composed of (1) Map Analyser, (2) Map Editor, and (3) Map Database, and then these subcomponents are connected through the network to each other. There are two kinds of map editors, one is for a teacher and the other is for a learner. Figure 5 shows Map Editor for Learner and Figure 6 shows Map Analyser. KB map system has been practically used as an assessment method of learner understanding and as a task to promote learner understanding in various learning contexts. For example, (i) science learning in an elementary school (Sugihara 2012), (ii) English learning as second language for university students (Alkhateeb 2015), (iii) social studies in a junior high school (Nomura 2014), and so on. In this section, several practical uses of KB map system are introduced.

Usages in Elementary School Science Class

We have practically used KB map system in several elementary school science classes (Sugihara 2012; Ambekar, 2015; Ramlawati, 2019). Examples of the topics are "the cycle of waxing and waning Moon", "sun and shadow", "electricity and light", "electromagnet", "structure of plants", "structure of insects" and so on. Figure 5 and 6 are concrete examples of the practice in the classroom of "the cycle of waxing and waning Moon". In this subsection, as an example of practical uses of KB map system, an instance for "the cycle of waxing and waning Moon" for seventy-two 4th grade students in two classes is described. In this use, we evaluated feedback with a difference map by a teacher (one class) and compared it with the usual feedback without a difference map (one class).

In this use, the students received three lectures (45 minutes per a lecture) of "the cycle of waxing and waning Moon" before the use of the KB map system. In this use, each learner used a tablet PC and built a map by direct manipulation as shown in Figure 7. In the first use of KB map, they build individual maps of "waxing and waning of the Moon" with KB map system

for thirty minutes in a class after the introduction of the operation of KB map. The map built in this class is called “first map”. After a week of use, the teacher in charge of the two classes gave a feedback lecture. For one class, the teacher gave feedback with the group difference map, as shown in Figure 8. In the map, visualization of the links is controlled by the overlaid numbers of the links. Figure 8 means that both “ring link between Noon and Waning Moon” and “setting link between Waxing Moon and Midnight” are included in many learner maps as excess links, and then, both “rinsing link between Noon and Waning Moon” and “setting link between Midnight and Waning Moon” are not included in many learner maps.

Regarding another class, the same teacher gave feedback based on the results of the pre-test. This is a usual feedback for exercises or examinations in a usual class. This class is a control group and the class with the map feedback is an experiment group. All the students, then, built again the maps of “Waxing and Waning of the Moon” with KB map system a week later. This map is called “second map”. Two weeks later of the map use lessons, the same test with the pre-test was carried out as a post test. The lectures were conducted with the same teacher in charge of the two classes (Dyen, 1975; Ling, Lin, Ke, & Chen, 2015; Yang, Chen, & Tang, 2001).

Analysis of map scores and test scores are shown in Figure 9,10 and Table 2. Table 3 shows the results of the questionnaire. These results suggest the effectiveness of KB map system for assessment methods and learning tasks. Practice in several other topics in science learning in elementary school have been reported (Pailai 2017; Law, 2018).

Kit-Building as a Clear Goal of Reading Comprehension in EFL Learning

In EFL learning, KB map is used as a clear goal of reading comprehension. Although reading comprehension is a basic task in EFL learning, the goal of a reading comprehension task is not clear. Reading comprehension is usually evaluated by using a question-answer exercise about content, however, to answer the questions is not the direct goal of reading comprehension. In this use, a concept map is generated for a text as an expression of adequate comprehension for the text. Then, the kit is prepared by decomposing the map, and the kit is provided for a learner. The learner is required to reconstruct the original map by using the kit. Figure 11 shows a concept map to a text and Figure 12 shows a kit.

Through this investigation, we have experimentally confirmed that KB map building is a more effective task for reading comprehension than the concept map scratch-building task from the viewpoint of recalling and remembering the reading contents (Mohammad 15; Ulum, 2016). The reason for the effectiveness, then, is that KB map building promotes an avid sentence-by-sentence reading style in comparison with scratch-building (Mohammad 16a). Additionally, it is confirmed that KB map building task is more effective for learning than selective underling task in reading comprehension (Mohammad 16b).

VALIDITY OF AUTOMATIC ASSESSMENT

One of the most important characteristics is automatic assessment of a concept map by direct comparison with a teacher map. Comparison with a teacher map or criteria map is a basic assessment strategy commonly used for both automatic assessment and manual assessment. In KB map, because all nodes and links are common with the teacher map and a learner map, it is possible to realize proposition (compose of two nodes and a link) level assessment only by comparing the location of each link. In order to investigate validity, the automatic assessment method of KB map was compared with several manual assessment methods experimentally (Wunnasri 2018a). In this research, two manual assessment methods were used for comparison: (1) structural scoring (Novak 84) and (2) relational scoring (McClure 90).

In this experiment, (a) a learner was requested to read a text. (b) the learner was then required to make a concept by using provided nodes and by creating links and their linking words. Concept map building with provided nodes and free linking is a popular practise adopted by many researchers. The two manual methods are formalized ones for the same setting. In this phase, Cmap Cloud application was used (Cmap Cloud 2017; Soria, 2018) and the concept map made in this phase is called “link free map”. (c) Just after building the link free map, the learner is also requested to build KB map. Here, both the link free map and the KB map are assumed to represent the same understanding of the text. Subsequently (Kumaran, 2015; Rosen & Mosharraf, 2020), the link free map is assessed by the two manual methods and the KB map is assessed automatically. The map that was used as a criteria map in the two manual methods was the same one with the teacher map in KB map assessment. Twenty-two university students attended as subjects and four university students who were familiar with the use of concept map and the experiment material were made raters.

The scores of maps calculated by each manual method for free link maps are shown in Table 4. The score of KB map scoring is calculated by the automatic assessment for KB map. In order to check the validity of scores of manual methods, values of g-coefficient of each manual method were calculated as shown in Table 3. Because the values were better than the values reported in McClure’s study (McClure 1999), it was judged that the scores were reasonable ones. Table 3 also shows the correlation in scores between each manual method and KB map method. Because of the statistically significant high correlations, the validity of automatic assessment with KB map was confirmed in comparison with manual assessment methods. Table 5 shows that participants thought that it was easy to express their understanding with KB map. These results suggest that the validity of automatic assessment of KB map is almost the same as the validities of well-known formalized manual assessment methods.

RECIPROCAL KIT-BUILDING FOR COLLABORAITIVE WORK

Framework of Reciprocal Kit-Building

"Understanding about "partner's understanding"" plays a crucial role in collaborative work or learning. This understanding is called "mutual understanding" in this research. As a method to promote mutual understanding, reciprocal kit-building (Wunnasri 18b; Sadita, 2018) is introduced. The framework of reciprocal kit-building is shown in Figure 13. In the framework, a participant (Participant B) builds a concept map as an expression of his/her understanding (1) free concept map building). Another participant (Participant A) then builds a concept map using the provided kit (2) re-construction of the concept map built by Participant B. By comparing map α0 with map α1, a difference map is automatically generated. Based on the difference visualized map, the participants are able to check the differences and similarities of their understanding. Although Figure 13 describes only the reconstruction by Participant A, it is necessarily the same procedure for Participant B. Reciprocal kit-building is composed of the two reconstructions by both participants.

Experimental Evaluation of Reciprocal Kit-Building

Reciprocal kit-building has been implemented by using KB map system and an experimental evaluation has been conducted. In the experiment, pair discussion supported by reciprocal kit-building (RKB group) was compared with pair discussion supported by normal concept map (NCM group). The results of the experiment were analysed using three metrics: (1) types of talks, (2) similarity of concept map, and (3) questionnaires. Figure 14 shows that there wer much more productive talks (disputative, cumulative, and exploratory talk) (Mercer 1996) in RKB group than in NCM group. Table 6 shows that maps in RKB group became more similar than in NCM group, and pairs in RKB group more accurately guessed their partner's understanding than in NCM group.

Table 7 shows the results of questionnaires. The participants of both groups almost accepted that the concept map was useful to express their understanding and to promote their discussion. There is no difference between the reciprocal kit-building and normal concept map. From an open-ended question that requested them to give their opinion on the reciprocal kit-building, many participants in the RKB group mentioned that Reciprocal kit-building was a novel activity for them. Most of them commented that reconstructing the original concept map of their partner was fun and like playing a game, and that the activity promoted them to understand each other. They also stated that the 10 minutes provided time for discussion was not enough. These results suggest that reciprocal kit-building promoted the pair discussion more than a normal concept map (Anohina-Naumeca, 2012; Calafate, Cano, & Manzoni, 2009; Park & Calvo, 2008).

CONCLUSIONS

This paper describes a framework of KB map, practical uses in classrooms, validity of automatic assessment of KB map, and reciprocal kit-building as a usage of KB map in a collaborative situation. These results suggest that KB map is a promising approach to the practical use of a concept map in the classroom. Extending the applicable domains and the analysis of the process of kit-building related to learning effects from this research project is important work that should be undertaken in the future.

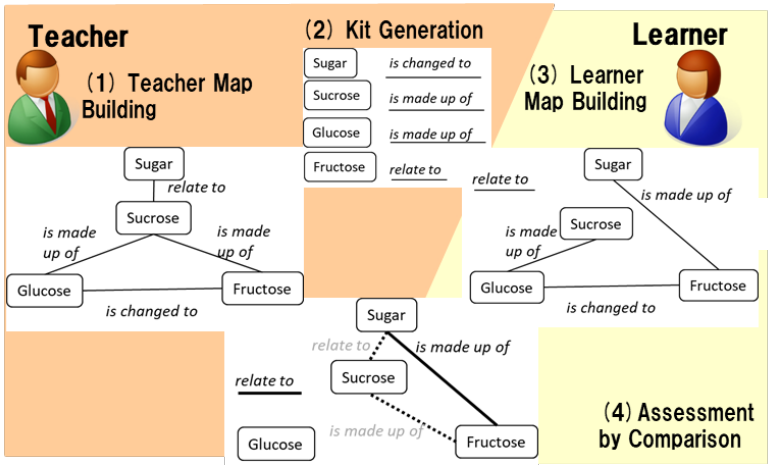

Figure 1. Practical Flow of KBC map.

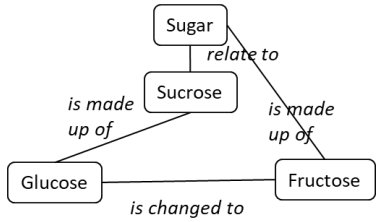

Figure 2. A Learner Map.

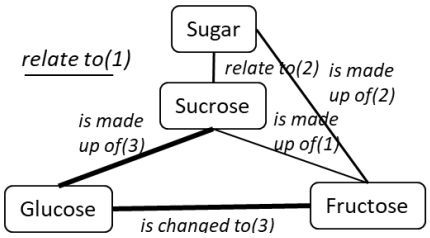

Figure 3. Group Map.

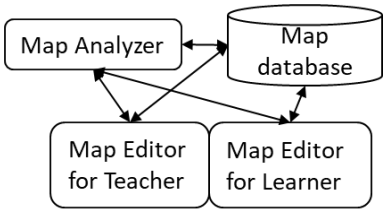

Figure 4. KC Map System.

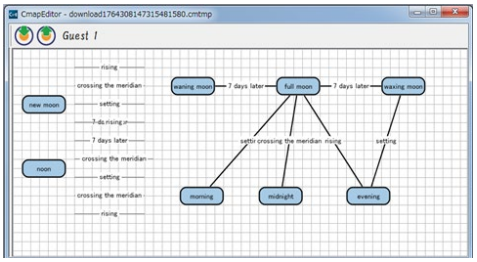

Figure 5. Map Editor for Learner.

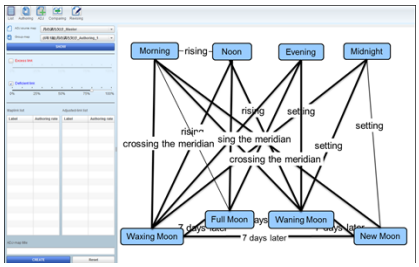

Figure 6. Map Analyser.

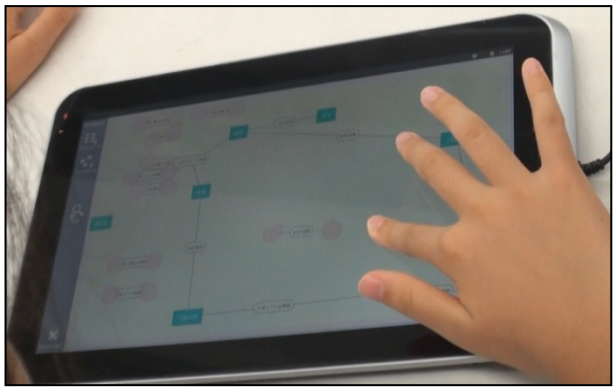

Figure 7. KB Map Editor on Table PC

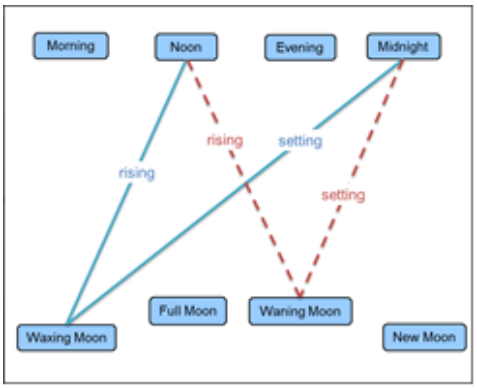

Figure 8. Group Difference Map (Visualized only major difference).

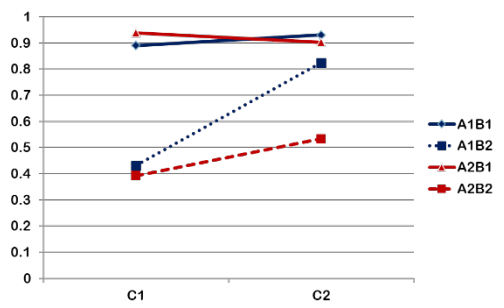

Figure 9. Map Scores

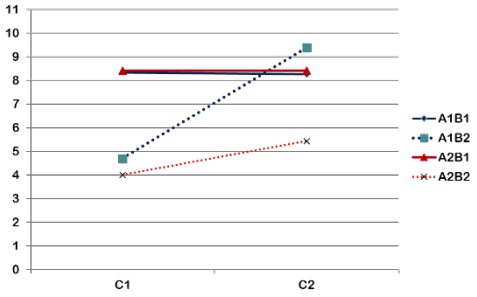

Figure 10. Test scores

A1: Map teaching class, A2: Usual teaching class, B1: High score students in pre-map, B2: Low score students in pre-map, C1: Pre-map, C2: Post-map

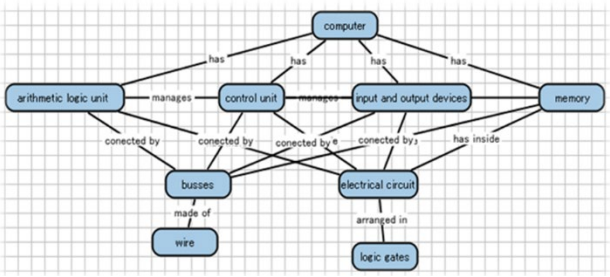

Figure 11. A Goal Map for Reading Comprehension

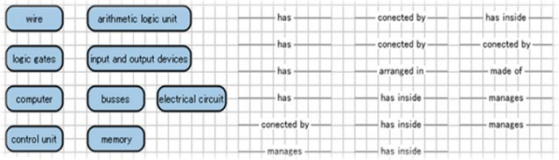

Figure 12. Kit

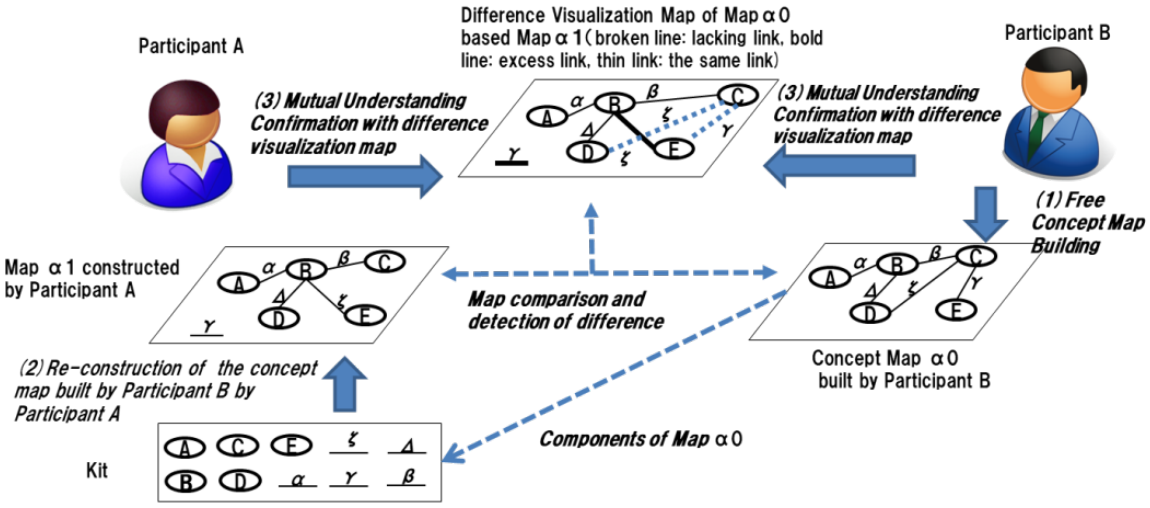

Figure 13. Framework of Reciprocal Kit-Building

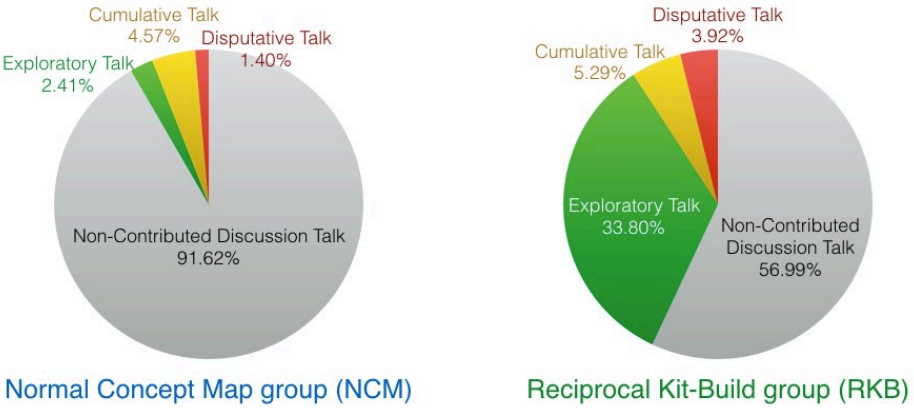

Figure 14. Types of Talks.

Table 1. A Categorization of Map Building Styles.

Open-ended	Free map	Any concepts and link words are allowed to use
Closed-ended	Link free map	Although available concepts are provided, any link words are allowed to use
	Construction free map	Although available concepts and link wards are provided, any construction are allowed as representation of learner's understanding structure
	Re-constructional map	Requested to reconstruct the original map by using provided components as assessment how the learner understand what the teacher was trying to convey through a lecture or learning material.

Table 2. Correlation between Map Scores and Test scores (*N*=142)

Table 3. Results of Questionnaire for Learners

	Map-building is enjoyable 0.45	Map-building is useful to learn the Moon 0.4E-08	Hope to use map-building at other subjects
Map Class (N=35)	4.00	3.92	3.90
Usual Class (N=32)	3.83	3.60	3.89

Table 4. Scores of learner map, G-coefficients and Correlation coefficients.

	Score(SD)	G-coefficients (reported G-coefficient)	Correlation coefficients between KB map scores
Structural Scoring	19.9(11.1)	0.75 (0.23)	0.7360(p< 0.01)
Relational Scoring w/o Criteria	29.7(15.4)	0.87 (0.51)	0.8532(p< 0.01)
Relational Scoring w/ Criteria	38.8(14.9)	0.89 (0.76)	0.8671(p< 0.01)
KB map Scoring	23.5(23.2)	1 (-)	

Table 5. Results of Questionnaire.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
It was easy to express understanding using Cmap	0%	5%	18%	73%	5%
It was easy to express understanding using KB map	0%	5%	0%	36%	59%

Table 6. Similarity of Maps

Average Score	NCM Group	RKB Group	
Before Self-Comprehension map and Before Partner's Comprehension map	29.39(SD=16.69)	35.83 (20.30)	
After Self-Comprehension map and After Partner's Comprehension map	49.04 (32.08)	61.85 (26.56)	+
Inference Partner's Comprehension map and After Partner's Comprehension map	46.57 (29.52)	61.15 (22.16)	*

+ Marginal difference between NCM and RKB groups (p-value < 0.1)
* Significant difference between NCM and RKB groups (p-value < 0.05)

Table 7. Results of Questionnaires.

No.	Statement	Group	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1	I understand the article well.	NCM	19.15	46.81	25.53	8.51	0.00
		RKB	38.30	36.17	21.28	4.26	0.00
2	Building concept map that represents my understanding was easy.	NCM	17.02	44.68	23.40	14.89	0.00
		RKB	29.79	27.66	36.17	6.38	0.00
3	When I disagree or confused about my partner's understanding, I can request him/her to additionally explain that point clearly.	NCM	17.02	36.17	36.17	8.51	2.13
		RKB	31.91	29.79	31.91	6.38	0.00
4	During the discussion, (normal concept map OR comparison map) can support by guiding our discussion well.	NCM	29.79	38.30	25.53	6.38	0.00
		RKB	27.66	36.17	31.91	2.13	2.13
5	We can have a satisfying discussion about the same and different understanding on a topic by using (normal concept map OR Reciprocal Kit-Building).	NCM	34.04	36.17	23.40	6.38	0.00
		RKB	34.04	27.66	29.79	8.51	0.00
6	After the discussion, I can understand my partner's understanding well.	NCM	21.28	46.81	27.66	2.13	2.13
		RKB	27.66	42.55	27.66	2.13	0.00

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