VALIDITY INVESTIGATION OF RECONSTRUCTIONAL CONCEPT MAP AND ITS COLLABORATIVE USE FOR SHARING UNDERSTANDING

（再構成型概念マップの妥当性の検証と
理解共有のための協調的利用に関する研究）

by

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DISSERTATION SUMMARY

Several previous researches of Kit-Build concept map (KB map) have shown that it is suitable for use in teaching situation where the instructor gives directions followed by instructor's interpretation. However, the assessment method of KB map has not been previously compared with other well-known manual methods that are also used practically. Although the automatic assessment method has advantages over manual assessment, for example, real time assessment/feedback, load reduction of the rater/teacher, etc., the quality of automatic assessment requires investigation. As an investigation of the validity of this method, an experiment was conducted as a case study to compare the assessment results of the method with the assessment results of two other manual assessment methods. In this experiment, the map scores which were evaluated by manual methods were confirmed the reliability by using g-coefficient value. Then, the scores of the KB method was found that they had a very strong correlation with the scores of the other manual methods. The results of this experiment are one of evidence to show the automatic assessment of the Kit-Build concept map can attain almost the same level of validity as well-known manual assessment methods.

In the validity investigation, the participants also confirmed that they can use KB map for expressing their understanding. Hence, KB map should support the participants to share their understanding to each other clearly. A collaborative use of KB map called "Reciprocal KB map" is proposed. In a Reciprocal KB map for a pair discussion, at first, the two participants make their own concept maps expressing their comprehension. Then, they exchange the components of their maps and request each other to reconstruct their maps by using the components. The differences between the original map and the reconstructed map are diagnosed automatically as an advantage of the KB map. Reciprocal KB map is expected to encourage pair discussion to recognize the understanding of each other and to create an effective discussion. In an experiment reported, Reciprocal KB map was used for supporting a pair discussion and was compared with a pair discussion which was supported by a traditional concept map. The results of the experiment were analyzed using three metrics: a discussion score, a similarity score, and questionnaires. The discussion score, which investigates the value of talk in discussion, demonstrates that Reciprocal KB map can promote more effective discussion between the partners compared to the traditional concept map. The similarity score of concept maps demonstrates that Reciprocal KB map can encourage the pair of partners to understand each other better compared to the traditional concept map. Last, the questionnaires illustrate that Reciprocal KB map can support the pair of partners to collaborate in the discussion smoothly and the participants accepted this method for sharing their understanding with each other. These results suggest that Reciprocal KB map is a promising approach for encouraging pairs of partners to understand each other and to promote the effective discussions.

The thesis consists of five chapters. In **Chapter 1**, the research context and the goals of the study, contribution, evaluation methods, and the structure of the thesis are described. **Chapter 2** outlines the concept map assessment methods including the manual concept map assessment methods, KB map, and the automatic concept map assessment methods. **Chapter 3** presents the validity investigation on the concept map assessment method. Steps of investigation were explained in detail following the procedure of each manual method, the evaluation method to confirm the reliability of the manual method, and the statistical analysis to compare the validity of KB map and the manual methods. In **Chapter 4**, an applied collaborative learning technique with KB map is described as Reciprocal KB map. This applied procedure aims to encourage the participants to share their understanding to their partner in pair discussion, including make their discussion actively. The procedure of Reciprocal KB map was explained step by step, then the content would mentioned to the produced preliminary experiment. To analyze the results, three aspects: a discussion scoring, a similarity map scoring and an interpreting questionnaires are utilized for explained the ability of Reciprocal KB map. The results of preliminary experiments demonstrate that this collaborative use of KB map can utilized for sharing understanding. And the participants also accepted that it is interesting and useful for sharing their understanding to each other. Moreover, to compare with the discussions which utilized from the traditional concept map, the discussions did not go continue smoothly. There are a lot of silence gaps in discussion phase of the participants who used the traditional concept map. While the participants from Reciprocal KB group continued their discussion smoothly. Finally, **Chapter 5** explains the conclusion of this thesis and future work directions.

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PREFACE AND NOTES

Publications

Journal articles

IEICE 2018: Wunnasri, W., Pailai, J., Hayashi, Y., & Hirashima, T. (2018). Validity of Kit-Build method for assessment of learner-build map by comparing with manual methods. *IEICE Transactions on Information and Systems, E101*(4), pp.1141-1150.

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IEICE 2018: Wunnasri, W., Pailai, J., Hayashi, Y., & Hirashima, T. (2018a). Reciprocal Kit-Build concept map: an approach for encouraging pair discussion to share each other's understanding. *IEICE Transactions on Information and Systems, E101*(9).

Conference papers

AIED 2017: Wunnasri, W., Pailai, J., Hayashi, Y., & Hirashima, T. (2017). Reliability investigation of automatic assessment of learner-build concept map with Kit-Build method by comparing with manual methods. *Proceeding of the 18th International Conference on Artificial Intelligence in Education*, Wuhan, China, pp.418-429.

AIED 2018: Wunnasri, W., Pailai, J., Hayashi, Y., & Hirashima, T. (2018b). Reciprocal Kit-Building of concept map to share each other's understanding as preparation for collaboration. *Proceeding of the 19th International Conference on Artificial Intelligence in Education*, London, United Kingdom, pp.599-612.

<u>Workshop Papers</u>

ICCE 2016: Wunnasri, W., Pailai, J., Hayashi, Y., & Hirashima, T. (2016). Reliability Investigation of Automatic Evaluation of Kit-Build Concept Map by Comparing with Handmade Evaluation Methods. *Paper presented at the 3rd Workshop on Emerging Pedagogies for Computer-Based Learning of the 24th International Conference on Computers in Education*, Mumbai, India, pp.199-208.

ICCE 2016: Wunnasri, W., Pailai, J., Hayashi, Y., & Hirashima, T. (2016). Comparison of Concept Map Evaluation between Kit-Build Method and Handmade Method. *Paper presented at the Working in Progress Poster session of the 24th International Conference on Computers in Education*, Mumbai, India, pp.4-6.

<u>Doctoral Student Consortium</u>

ICCE 2016: Wunnasri, W., Pailai, J., Hayashi, Y., & Hirashima, T. (2016). Investigation of Reliability of Kit-Build Concept Map and Collaborative Approach to Build Sharable Knowledge. *Paper presented at the Doctoral Student Consortium session of the 24th International Conference on Computers in Education*, Mumbai, India, pp.9-12.

Source and Original Work

Original material of my own from the above publications has been included in this thesis, with a citation to the appropriate publication appearing at the beginning of each chapter. Other external sources are cited, with the bibliography appearing at the end of the thesis. All figures are created originally by my own for supporting the above publications.

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CHAPTER 1

INTRODUCTION

Summary: The research context of the thesis, the identified research problem and the methodology will be described in this chapter. The thesis proposes the validity investigation of Kit-Build concept map (KB map) by comparing with the well-known manual concept map assessment and proposes the procedure to utilize KB map for sharing understanding in pair discussion as Reciprocal KB map. Then the results of utilization will be analyzed as three viewpoints following the discussion score, the similarity concept map score, and the interpretation of questionnaires. This chapter outlines the goals, contributions, evaluation methods and the general structure of the thesis.

1.1   Context and Motivation

A theory of an assimilation of new knowledge into existing knowledge was proposed in Ausubel et al.'s research (Ausubel, 1978). This theory was applied by Novak and Musonda to be a concept map, which they used to investigate changes in children's knowledge of science (Novak & Musonda, 1991). The concept map represents conceptual understanding via connecting line between two or more concepts. The lines accompany with phrases as linking words for specifying the relationship between concepts (Novak & Cañas, 2008). The concept map can be used as a graphical tool for organizing and representing knowledge extensively. Also, it can help learners to significantly reduce their learning cognitive load because concept maps assist in t
he integration of knowledge and facilitate learners in their independent learning and thinking (Hu & Wu, 2012). Moreover, it can be utilized as a technique for increasing student's learning in a traditional classroom (Vanides et al., 2005; Francisco et al., 2015; Samarawickrema, & O'Reilly, 2003). Afterward, the concept map is used for evaluating learners' understanding. Several concept map evaluations were proposed. Many criteria were applied to evaluate concept maps following each specific objective. Novak and Gowin mainly used structural of concept map for scoring (Novak & Gowin, 1984). Crosslink, link

is connected between two different segments, receives the highest priority in this method for evaluating learner's creativity. Relational scoring of McClure and Bell pays the attention to meaning of each proposition in concept map for assessing learner's understanding (McClure & Bell, 1990). This method is more meaningful scoring than the structural scoring of Novak and Gowin. Rates should consider about the objective of evaluation before choosing the scoring method for evaluating concept map. These assessment methods which were used to evaluate learners' concept map manually are accepted widely, but they entail high costs, such as time and human workload, for scoring each concept map. Hence, an automatic concept map assessment is proposed for decreasing time cost and human workload.

The motivation of study is to examine the validity of KB method by comparing with the concept map manual methods, which is examined the reliability already. Because KB map is an automatic method and provides the all components that are extracted from the teacher-build map to learners, the investigation aims to prove the provided components of KB map do not support learners too much and they do not disturb learners to express the understandings. So, the validity investigation is needed for confirm that the evaluation of KB method is as same level as the reliable manual methods that is used widely.

After confirming that the provided components of KB map do not disturb learners to express their understanding, KB map would be assumed that it can be an effective instructional medium for sharing understandings, so the collaborative use of KB map called "Reciprocal KB map", was designed for encouraging the sharing understandings with each other in pair discussion. To confirm the effectiveness of Reciprocal KB, the preliminary experiment was produced by comparing between the discussion, which using the medium as the traditional concept map and Reciprocal KB map.

1.2   Thesis Statement

This thesis aimed at examining the validity of KB map assessment method by comparted to the reliable manual concept map assessment methods and designing the collaborative use of KB map for sharing understanding in pair discussion. The quality of discussion and their shared understandings are considered in this thesis. The thesis statement is stated as follows:

> To investigate the validity of Kit-Build concept map and confirm that its assessment method can attain almost same level with the reliable manual concept map assessment method and to design the collaborative use of KB map for sharing the understanding in pair discussion.

1.3   Thesis Goals

From the research context and stated the thesis statement, the main goals of the thesis are formulated following:

1. *Investigate the validity of Kit-Build concept map compared to the manual concept map assessment methods:* Two manual concept map assessment methods which were investigated the reliability of assessment were compared with the assessment method of KB map, which evaluate the concept map automatically.

2. *Design the collaborative use of KB map for sharing understanding in pair discussion:* If the participants can use KB map to express their understanding well, KB map is possible to use for sharing the understanding to the others. In the first step, the collaborative approach is applied to KB map for encouraging the participants to share their understanding in pair discussion.

3. *Examine the difference between the discussion using the traditional concept map and the discussion using Reciprocal KB*: Normally, the traditional concept map is used widely such as organizing, representing, checking the knowledge, or discussing. To prove that the purpose that KB map can be used for sharing understanding to each other, the traditional concept map is used to compared and examines the same and different effects from the different discussing medias.

1.4   Thesis Contributions

The main contribution of this thesis is the confirmation that the validity of KB map assessment method can attain almost same level with the reliable manual concept map assessment methods and the procedure of collaborative use of KB map for sharing understanding in pair discussion. The contributions are described as follows:

1. *Examine the expressing understanding of participants during they were using KB map:* To confirm that KB map can be used almost the same level with the traditional concept map, the experiment was conducted. If the results show that the provided components of KB do not disturb the participants to express their understanding, this evidence can support the assumption to use KB map for sharing the understanding in the collaborative work.

2. *Evaluate the discussion when the participants tried to share their understanding to each other*: To compare the discussion which were supported by the traditional

concept map and the discussion which were supported by the collaborative use of KB map, categorization by using the type of talk (Mercer, 1996) is applied. This criterion can emphasize the useful of each conversation clearly.

3. *Evaluate the shared understanding:* To confirm that the participants understand their partner's understanding, the relational concept map assessment is used for scoring the similarity value between each pair of participants. Because the experiment procedure allows the participants to create the linking words by themselves, this manual concept map scoring suite for evaluating more flexible than the exact matching.

1.5   Research Methodology and Validation Methods

To reach the goal of this thesis, the experiment which requested the participants to use both traditional concept map and KB map was conducted. The validation approach of this experiment can be described as follows:

1. *The concept map assessment method:* The concept maps which were constructed from the traditional concept map were evaluated by the manual concept map assessment while the concept maps which were constructed by using KB map were scored by the KB system.

2. *The reliability score of the manual methods:* To evaluate the concept map without the bias of rater. Four rates were requested to score the participants' maps and their score would be averaged to be the final score of each concept map. The scores of the manual assessment would be used to calculate the g-coefficient which can be explained the consistency of raters, can be called the reliability score.

3. *The correlation value:* The score from the manual methods and from KB system would be calculated the correlation to confirm the results between two methods are in the same way or the different way.

For the second experiment which aim to confirm the ability of KB map for sharing understanding in pair discussion and make their discussion actively, the validation approach of this experiment can be described as follows:

1. *Quantitative and Qualitative analysis of the discussion:* For the quantitative, the conversation on each proposition would be counted and that conversation would be categorized into the types of talk depended on its characteristic.

2. *The concept map assessment:* To find the similarity of concept map, the relational concept map assessment was selected as the evaluation tool because the partner's

map would be used as a criteria map and the roles of evaluation are flexible and proper for the concept map that the constructor can create the linking words freely.

1.6   Thesis Structure

This section describes the chapters of the thesis. Figure 1-1 illustrates the structure of the thesis and the publication associated with each chapter.

Chapter 1 – Introduction: describes the research context and outlines the goals, contributions, evaluations methods, and the general structure of the thesis.

Chapter 2 – Background: outlines relevant research of the manual concept map assessment methods including the research and the practical uses of the KB map.
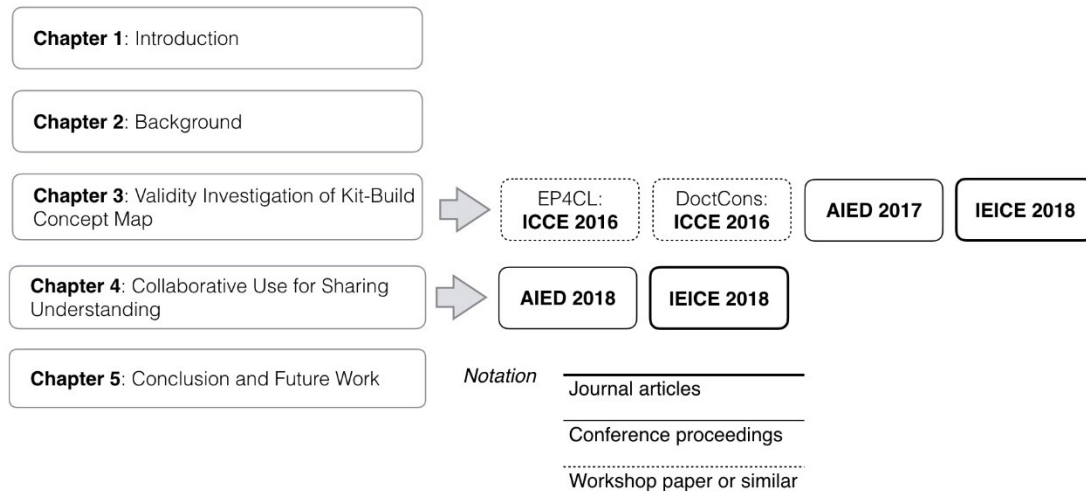
Figure 1-1 *Structure of the research covered in this thesis and related published paper*

Chapter 3 – Validity Investigation of Kit-Build Concept Map: This chapter describes the validity investigation procedure of KB map compared to the well-known manual concept map assessment methods. The procedure of investigation is explained in detail.

Chapter 4 – Collaborative Use for Sharing Understanding: This chapter focused to the collaborative use of KB map which aim to encourage the sharing the understanding in pair discussion and make their discussion actively. The results are explained in three aspects: the discussion, the similarity of concept map, and the interpretation of questionnaire.

Chapter 5 – Conclusion and Future Work: The conclusion of all tasks and the promising research avenues for future studies are mentioned in this chapter.

BACKGROUND

Summary: This chapter reviews the concept map assessment methods which are used for scoring concept map by human. Moreover, about the KB map which is the focused strategy of this thesis, its abilities, its procedure, the diagnosis results through the practical use in schools will be explained.

1.1 Manual Concept Map Assessment Methods

A manual concept map assessment method is used by a human who can understand the meaning of words in the concept map well. The human is often called a "rater". In this study, we focus on the methods that pay attention to the structure of a concept map and the meaning of the proposition of a concept map.

Several concept map assessment methods evaluate the concept map by investigating the structure of the map, such as, the levels of the hierarchy, the characteristics of the branch, etc. In this study, we focus on the structural scoring of Novak and Gowin (Novak & Gowin, 1984) as a typical structural method. This method gives high scores for each correct level of the hierarchy and each valid crosslink because ordering the concepts into the hierarchy, and connecting the crosslinks, can facilitate the constructor's creative thinking. However, structural scoring, which tends to score the structure more than the meaning, may be the cause of substantial meaning-leakage in a concept map.

Many manual assessment methods which pay more attention to the meaning of a proposition for scoring the concept map, rather than the structure, have been proposed. They focus on language and understanding of the representation. These meaningful methods always have a printed set of criteria as the rubric for assessing knowledge and giving feedback. From investigating various meaning methods, we focused on the relational scoring from McClure and Bell, which is referred to as relational scoring in this paper, and is a common concept map assessment method. This method scores the concept map by checking the possible relationship between each proposition, suitability of label between concepts of

proposition and compatibility between label and the direction of arrow or hierarchical (McClure and Bell, 1990).

There are many researches which invested on the reliability and validity of concept map assessment. Ruiz-Primo focused on reliability and validity of scores from two concept mapping method which are high directed "fill-in-a-skeleton-map" and low directed "construct-a-map-from-scratch". Fifty-five learner-build maps were scored by three raters and the scores across taters were used to examine the generalizability coefficient (g-coefficient) (Ruiz-Primo, 2004; Ruiz-Primo et al., 2011). The correlation between two concept mapping methods and multiple-choice test was used to show the validity. In Ruiz-Primo's study, they concluded both mapping techniques are tapping somewhat similar but not identical aspects of learners' connected understanding. The correlation between score from the multiple-choice test and both concept map techniques confirmed that the mapping techniques were not equivalent. The pattern of correlation coefficient was different across mapping techniques. McClure et al. also investigated on the reliability and validity of concept map assessments (McClure et al., 1999), they requested 63 students to construct concept maps by using 20 provided concepts, creating their own linking words. Then, 12 raters scored individual maps by assessing each proposition on the concept map separately. The raters awarded scores of zero to three points for each proposition based on the suitability of the meaning of the proposition. The authors claimed that this relational method has the highest reliability when using the criteria map, (teacher-build map), using the holistic method and the structural method as comparisons (Novak and Gowin structural scoring). The authors confirmed this result by using the g-coefficient value as an estimate of the score reliability of scores assuming a single rater. For the analysis of validity, they investigated from the correlation of map scores with a measure of similarity between each map and the criteria map. Then, they conclude the relational scoring method with criteria map correlated most closely with maps' measure similarity. Based on these considerations, we have designed an experiment for testing the reliability of a manual method, similar to the experiment of McClure et al. We selected the structural scoring proposed by Novak and Gowin, and the relational scoring proposed by McClure and Bell, to compare with the KB map proposed in the current study because they are the typical manual methods which had been already proved the reliability and validity of assessment. Then, we investigated validity of KB method from the correlation of KB map scores with scores from the manual methods, similar to the McClure et al.'s experiment.

1.2 Kit-Build Concept Map

The Kit-Build concept map framework is one of the automatic concept map assessment methods that use a teacher-build map to compare with the learner-build map by using exact matching at the propositional level (Hirashima et al., 2011; 2015). It is utilized in the form of a learning task or exercise for checking learners' comprehension of a topic that they have already learned. The task of the KB map is separated into two subtasks. The first is the segmentation task where a teacher is requested to prepare the teacher-build map, which is an expression of an eligible comprehension of the topic for the teacher. An example of the teacher-build map is illustrated in Figure 2-1. After submitting the teacher-build map to the server, the teacher-build map is extracted to be the kit that contains a list of concepts and relationships from the teacher-build map. The kit from the teacher-build map in Figure 1 is shown in Figure 2-2. Moreover, this kit is provided to help learners to reduce their cognitive load more than the traditional concept map, where they must create all components themselves. Using the kit, the learners are not requested to create any component. They only have to recognize the provided components and connect them.
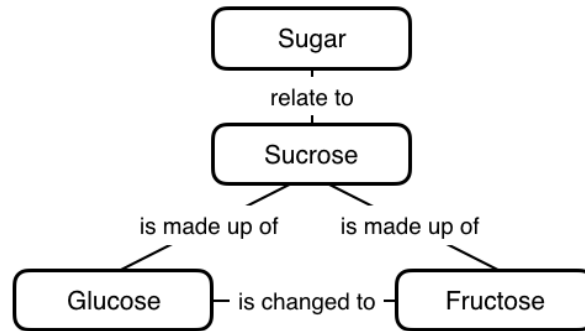
Figure 2-1 *Teacher-build map*
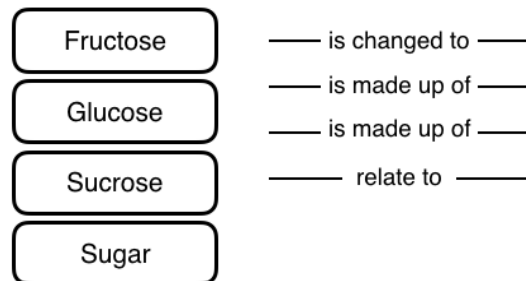
Figure 2-2 *Kit of the teacher-build map*
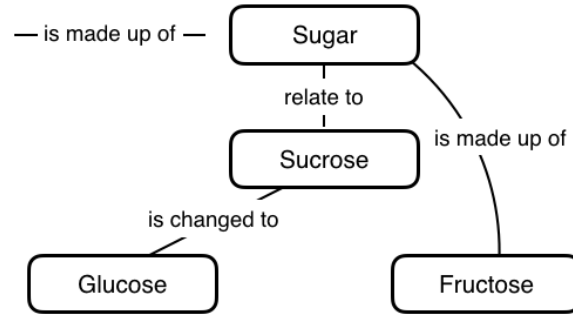
Figure 2-3 *Learner-build map*
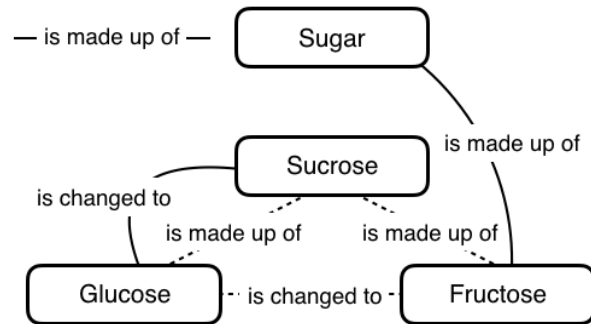
Figure 2-4 *Difference map*

The second task is called the structuring task. Learners are given the learning task of reconstructing a concept map by using the kit, creating a map which is referred to as the learner-build map (Figure 2-3). After the learner-build maps are uploaded to the server, the KB map will evaluate learner-build maps by exactly matching each learner's proposition with the teacher-build map's proposition. For example, the relationship between the concepts "Sugar" and "Sucrose" is checked. If the relationship is identified as "related to," the score for this learner-build map will increase by one point. In the case of the concepts "Sucrose" and "Glucose," if the learner connected them by using the relationship "is changed to," this does not exist in the teacher-build map. Following the teacher-build map, the relationship of this proposition should be "is made up of", so this proposition is not awarded any point from the system. This corresponds to the scoring by propositional level exact matching method. This method makes the KB map different from the manual methods which allow learners to create their own linking words, preventing the learner-build map from being straightforwardly compared with the criteria map. The manual methods require time for considering the meaning of each proposition carefully. After checking the connections of the learner-build maps by the propositional level exact matching, the system will generate a score in a percentage format which is calculated via the number of correct links of learner-build map divided by the number of links of teacher-build map. For the example, the learner-build

map in Figure 3 will be given 25 percent score from one correct link "relate to" divided by four links from the teacher-build map. The instructor can also investigate learners' misunderstanding individually as a difference map and can find the overview of all learners by overlaying all learner-build maps, as the group map, and the group-goal difference map on the analysis screen of the KB. In the difference map, three types of error link are represented as shown in Figure 2-4. The lacking link, which is represented by a dashed line, is a link that exists in the teacher-build map but does not exist in learner-build map. The excessive link, which is shown as a solid line, is a link that occurs in learner-build map but does not occur in the teacher-build map. Lastly, a solid line that is not connected to any concepts in the learner-build map is the leaving link. The instructor can use these links to find the holistic leaking under-standing of all learners. Following the KB map framework's ability, the instructor can use the KB map to check understanding of individuals or groups of learners, and can use the diagnosis result to discuss with learners the meaning of each of the error links. After error link analysis, the instructor can adjust the teacher-build map or teach learners about the content that learners have not understood completely. KB map and its automatic assessment method have already been practically used in classrooms in various schools, for example, in science learning in elementary schools (Sugihara et al., 2012; Yoshida et al., 2013), junior high schools (Nomura et al., 2014), and university (Hayashi & Hirashima, 2014; 2015). Also, it is proper for use in various educational fields such as English, science, and social science (Alkhateeb et al., 2014; 2015; 2016; Hayashi et al., 2016; Kitamura et al, 2016). And KB map had been investigated about the effect to memory retention in the experimental environment (Funoi et al., 2011). We have confirmed that teachers can use the feedback from KB map in their class effectively (Pailai et al., 2017).

In the other automatic methods (Luckie et al., 2004; Harrison et al., 2004; Kornilakis et al., 2004; Cline et al., 2010), they allow learners to create their own linking words so they cannot compare a learner-build map with the criteria map straightforwardly. Hence, they require synonym word matching, which is very flexible for evaluation using the meaning of words, but which has not yet reached a sufficient level of accuracy. In contrast, the KB map provides the kit which can be assessed by using the propositional level exact matching and can create informative diagnosis results. Moreover, the KB map can provide the group map and group-goal difference map, which can support the instructor in analyzing comprehension in both an individual learner and as an overview of the whole class. These are the prominent advantages of the KB map when it is utilized in a classroom situation.

VALIDITY INVESTIGATION OF KIT-BUILD CONCEPT MAP

Summary: This chapter describes an investigation into the validity of an automatic assessment method of the learner-build concept map by comparing it with two well-known manual methods. Kit-Build (KB) concept map framework is proposed as a learner builds a concept map by using only a provided set of components, known as the set "kit". In this framework, instant and automatic assessment of a learner-build concept map has been realized. This assessment method is called the "Kit-Build method" (KB method). The framework and assessment method have already been practically used in classrooms in various schools. As an investigation of the validity of this method, an experiment was conducted as a case study to compare the assessment results of the method with the assessment results of two other manual assessment methods. In this experiment, 22 university students attended as subjects and four as raters. It was found that the scores of the KB method had a very strong correlation with the scores of the other manual methods. The results of this experiment are one of evidence to show the automatic assessment of the Kit-Build concept map can attain almost the same level of validity as well-known manual assessment methods.

3.1   Introduction

Concept Map was developed in 1972 in Novak and Musonda's research program. They investigated changes in children's knowledge of science based on the learning psychology of group of Ausubel. In Ausubel 's research, they discussed the assimilation of new knowledge into existing knowledge by learners (Ausubel et al., 1978). A concept map represents conceptual understanding via connections between concepts. A concept in a concept map can be a term or symbol that is enclosed in a box, and a link is a line that is connected to two concepts. A linking word is a word on the link that represents the relationship between concepts. To build the concept map, creators have to organize their knowledge following their target. They can limit the scope of their concept map by constructing a concept map for answering the focus question. Then the creators build a concept list from the main idea of the content and order these concepts from general to more specific aiding in hierarchical

construction. Proposition of the concept map, or unit of meaning, can be constructed from linking two or more concepts via a proper relationship. The concepts should be ordered by placing the general concept in the top hierarchy and specific concepts at the bottom (Novak & Cañas, 2008). Moreover, concept maps can help learners to significantly reduce their learning cognitive load because concept maps assist in the integration of knowledge and facilitate learners in their independent learning and thinking (Hu & Wu, 2012). Due to these characteristics, the concept map is used to organize and represent knowledge extensively.

Afterward, the concept map is used for evaluating learners' understanding. Several concept map evaluations were proposed. Many criteria were applied to evaluate concept maps following each specific objective. Novak and Gowin mainly used structural of concept map for scoring (Novak and Gowin; 1984). Crosslink, link is connected between two different segments, receives the highest priority in this method for evaluating learner's creativity. Relational scoring of McClure and Bell pays the attention to meaning of each proposition in concept map for assessing learner's understanding (McClure and Bell, 1990). This method is more meaningful scoring than the structural scoring of Novak and Gowin. Rates should consider about the objective of evaluation before choosing the scoring method for evaluating concept map. These assessment methods which were used to evaluate learners' concept map manually are accepted widely, but they entail high costs, such as time and human workload, for scoring each concept map. Hence, an automatic concept map assessment is proposed for decreasing time cost and human workload.

From the practical uses of KB map, they represent that the KB map is suitable for use in teaching situation where the instructor gives directions followed by instructor's interpretation. However, we have not previously compared the KB method with other well-known manual methods that are also used practically. Although the automatic assessment method has advantages over manual assessment, for example, real time assessment/feedback, load reduction of the rater/teacher, etc., the quality of automatic assessment requires investigation. Normally, although the manual concept map assessment method is used by one teacher on their own way individually, McClure et al. tried to prove quality of several concept map assessment methods (McClure et al.; 1999) from viewpoints of reliability and validity. In McClure's research, validity is evaluated by correlation among assessment results of the same concept map and reliability is evaluated by g-coefficient among several raters. Their reliability and validity investigation procedures are explained clearly so we designed the experiment following their procedures. In our study, validity of KB method was evaluated by correlation with the manual methods reported to be of high quality in McClure's paper.

Although reliability of KB method is perfect because it is systematic and automatic method, we used this reliability to evaluate the results of quality of the manual methods conducted in this study. As the two manual methods, (1) structural scoring proposed by Novak and (2) relational scoring proposed by McClure and Bell were adopted. We conducted an experiment as a case of study where 22 university students were designated as subjects, and four were designated as raters. The results of the experiment showed that the scores of the KB method had a statistically significant correlation with the scores of the other manual methods. The results suggest that automatic assessment using the KB method can attain almost the same level of validity as well-known manual methods. Although the results of this experiment can be used as an evidence to represent of the validity of KB method, this is a case study. It is necessary to examine more several cases in order to confirm the generality of the validity.

3.2   Procedure of KB Map Validity's Investigation

In this research, we assume that assessment results of well-known manual methods have reliability and validity. Then, the validity of KB map is investigated by comparing with the results of manual methods. For this investigation, we designed an experimental procedure to compare the KB map and the manual methods in terms of their ability to assess the comprehension of learner on a topic. Usually, the KB map is used in teaching situations, however, it is desirable to ensure that the KB map as can be used in a reading situation also. Hence, the experiment was designed to operate in two learning situations. Moreover, to compare the difference between the KB map and the manual method, the important attributes of the concept map assessment method are shown in Table. 3-1.

Table 3-1 *The attributes of each concept map assessment method*

Assessment Method	Assessment			Provided Items	
	Raters	Level of Analysis	Matching Method	Concepts Words	Linking Words
Structural Scoring	Manual	Structural	Synonym	Provided	Not Provided
Relational Scoring	Manual	Propositional	Synonym	Provided	Not Provided
Kit-Build Concept Map	Automate	Propositional	Exact	Provided	Provided

Two typical scoring methods, which are widely used for assessing concept maps, namely the structural scoring as structural level analysis, and the relational scoring as propositional level analysis, were chosen for comparison. The manual method is inferred from the research of (McClure et al., 1999), who provided a list of concepts to learners and requested that they

construct concept maps by creating linking words themselves. The synonym matching method was used for evaluating the meaning of each proposition. However, the KB map provides both the concepts and the linking words, which are decomposed from the teacher-build map, to learners. Thus, the automatic exact matching method can be used for checking the correctness of each proposition.

3.2.1 Participants

Subjects for this study were recruited from university students who possessed a good level of English. The 22 students, who were volunteers from various education fields, were given the role of learners. They were given introductory training in concept maps before participating in the experiment. Four students, who were familiar with the use of the concept map and understood the content of the experiment material well, were assigned as raters. These raters were given an explanation of the procedure of each assessment method, and they were required to study the procedures carefully before scoring the learner-build map. In addition, one graduate student was assigned the role of instructor. The instructor was required to prepare the article and teaching material for the experiment and the instructor was also required to construct the teacher-build map following specific instructions. In this study, the article "Sugar", which uses common explanatory words, was chosen for the learning process so subjects who are from various faculties can understand without bias. This article contained three sections, covering one third of a page, defined as the introduction to sugar, types of sugar and how sugar is produced (Klaus, 2017).

3.2.2 Map Production

Initially, the instructor chose a 1,594 word article, prepared the teaching materials and built the teacher-build map. The teacher-build map, which was also used as the criteria map for manual methods contained 15 concepts and 16 relationships. In the study, the procedure of this experiment is displayed in Figure 3-1. Firstly, learners were requested to read the article in ten minutes (1), and they were then provided with the list of concepts. Next, they were required to create linking words by themselves for the construction of a concept map in 15 minutes using the Cmap Cloud application (2), as illustrated in Figure 3-2 (Cañas et al., 2004; The Institute for Human & Machine Cognition, 2017). These learner-build maps were scored by the two manual methods. The learners were then asked to construct a concept map again in 15 minutes by integrating the kit of the KB map (3), which provided both a list of concepts and a list of linking words. The initial representation of the KB map in this experiment is shown in Figure 3-3. After the learners had completely connected the propositions and

uploaded their map to the server, these learner-build maps were evaluated using the KB map assessment method based on exact matching at the propositional level.
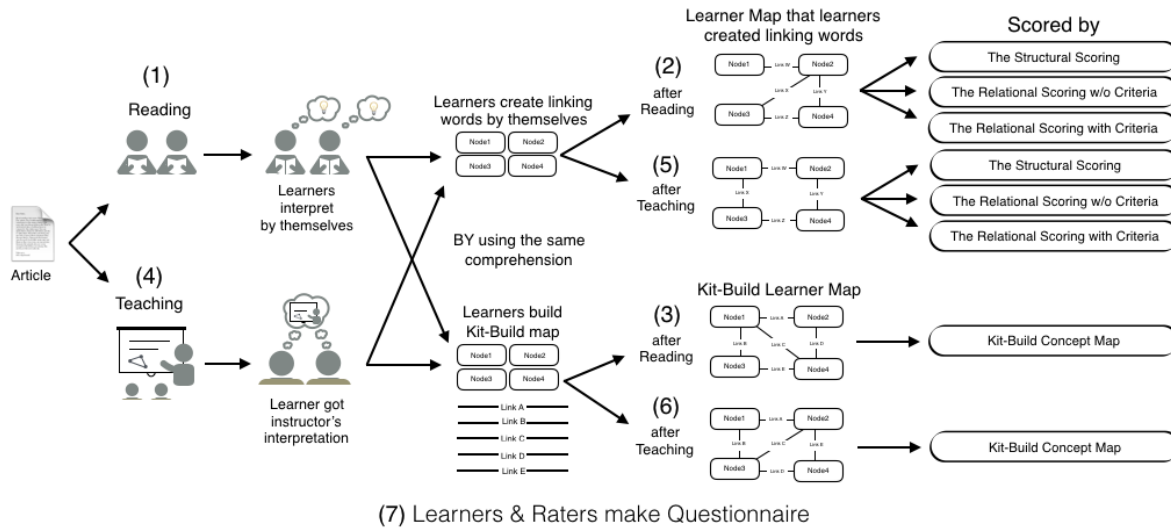
Figure 3-1 *Experiment procedure*
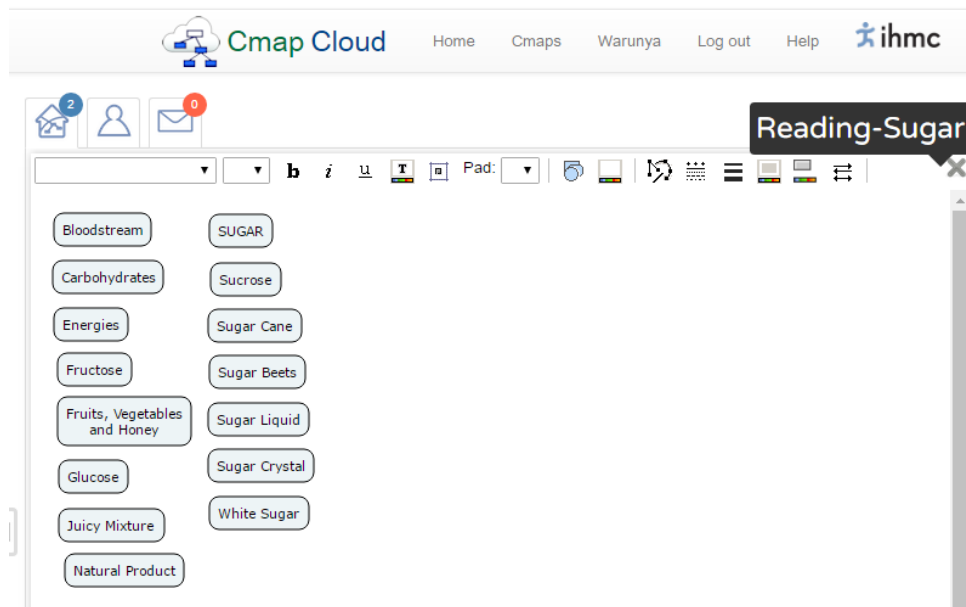
Figure 3-2 *Cmap Cloud screen*
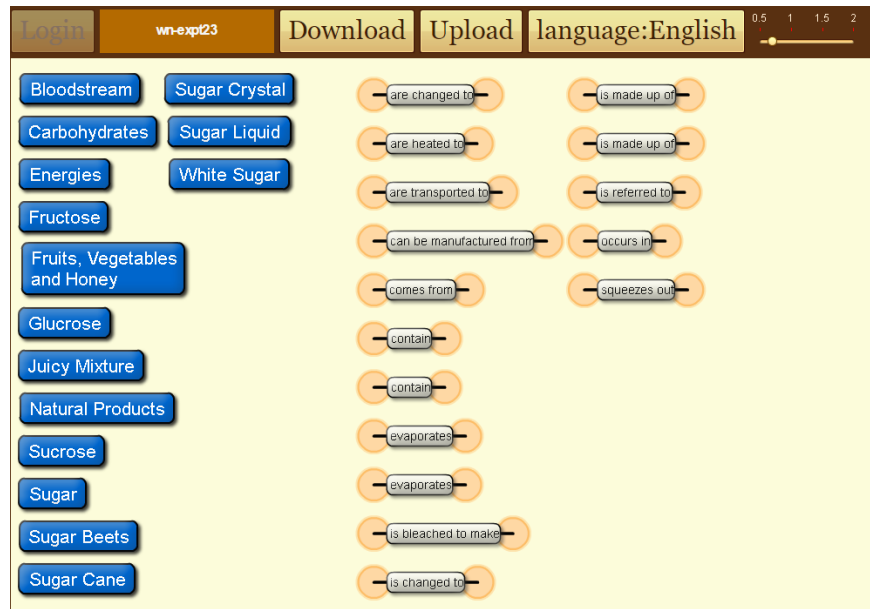
Figure 3-3 *Kit-Build concept map screen*

After the reading session concluded, the instructor taught learners based on the same reading article but following the instructor's interpretation using 16 slides delivered over ten minutes (4). Afterward, learners were required to construct the learner-build maps following the same procedure as in the reading situation, namely, constructing learner-build maps by creating linking words by themselves (5) and integrating the kit to create a learner-build map using the KB map (6). For the reason why we did not request learner to modify their previous concept map from reading situation but request for creating the new one, we aim to evaluate the concept map that learners constructed from their actual understanding in each learning situation. When learners completed all learner-build map construction, they were asked to answer a questionnaire (7).

For this experiment procedure, we designed for comparing a reflection of learners' understanding between concept map construction, which learners can create linking words freely, and KB map, which learners were provided both of the concept list and linking word list. If the provided components do not support learner too much and they do not disturb learners to express understanding, the results of KB method and the manual methods should be in the same way. So all subjects were requested to participate in all situations, which are usual concept map, KB map, reading situation, and teaching situation. For the order effects, we designed reading situation was produced before teaching because subjects should think by themselves before receiving the interpretation of teacher. In the same way, we requested subjects to create their linking words freely before they received the components from KB

map because subjects should feel free for creating the linking words. They should not be guided by the provided components of KB map.

3.2.3 Concept Map Scoring by Manual Methods

The concept maps, which were constructed using Cmap Cloud, were scored by three manual methods that contained, (a) the Novak and Gowin structural scoring (the structural scoring), (b) the McClure and Bell relational scoring without the criteria map (the relational scoring without criteria map) and (c) the McClure and Bell relational scoring with criteria map (the relational scoring with criteria map). The raters were required to read the instructions of each assessment method carefully without time restrictions. The score of the manual methods was normalized to a percentage score by using the perfect score for each method. After the scoring was completed, the raters were requested to complete the questionnaire. Procedures for each method were prepared based on the description in (McClure et al., 1999). The reliability of the results of the manual methods is discussed in Section 3.3.

3.2.4 Questionnaires

The questionnaires were assigned to both raters and learners to assess their familiarity with concept mapping and their opinion of the experiment. For the learners' questionnaires, the aim was to assess their background in concept mapping and in the content of the article. A further aim was to understand how their experiences differed when constructing the concept maps by creating their own linking words and when using the KB map.

For the raters, the questionnaire contained two parts. The first part of the questionnaire assessed their familiarity with the concept map and with the content of the article. The questionnaire also asked about their disposition when they were scoring the concept maps. The second part of the questionnaire is constructed based on conclusion of the important characteristics of each concept map scoring method in (McClure et al., 1999). We requested raters to rank each scoring method in four aspects covering (i) hardness of decision, (ii) use of memory, (iii) time taken and (iv) reasonableness of the score.

3.3 Experimental Results and Discussion

3.3.1 Correspondence of the KB Map and the Manual Method

To confirm the KB map's validity as a framework for assessing learners' comprehension of a topic by comparing with reliable manual methods, we aim to first investigate the reliability

of the manual methods. The scores from three manual methods: (a) the structural scoring, (b) the relational scoring without criteria map and (c) the relational scoring with criteria map and Kit-Build map are represented in Table 3-2. A difference of each scoring method effects S.D. value because the score of each link from the manual methods can be multiple scales (from zero to three points) while KB method scores one correct link as one point. The scores from manual methods were used to evaluate the reliability of each manual method by calculating g-coefficient value. After that, the score of Kit-Build map will be ensured the correlation with the score of reliability manual methods for confirming that Kit-Build method can attain almost the same level of validity as manual assessment methods.

The scores of learner-build maps from each manual method were used to perform generalizability analysis through the GNOVA software (Brennan, 1983) which returns the g-coefficient, as used in the reliability investigation by McClure et al. (McClure et al., 1999). The g-coefficient is analogous to the reliability coefficient in classical test theory (Webb, 2005). In this study, we interpret the g-coefficient as an estimate of score reliability assuming a single rater which shows the consistency of each scoring method as shown in Table 3-3. All values of g-coefficient of the current study are higher than values reported in (McClure et al., 1999). Then, the relational scoring with the criteria map resulted in the highest score reliability in both reading and teaching situations, which is consistent with the investigation of McClure et al. which indicated that the relational scoring method is reliable in assessing the concept map. Based on these results, we concluded that the manual assessment conducted in this research is reliable and it is possible to evaluate validity of KB map by comparing with the results of the manual assessment. As for the reason why the g-coefficient obtained in the current study is higher than that obtained by McClure et al. we guess that the current study was conducted with a smaller number of subjects and raters, that is, 12 raters in McClure et al., and four raters in the current study.

Table 3-2 *Score of learner-build map from each scoring method*

	Reading		Teaching	
	Average	S.D.	Average	S.D.
Structural Scoring	19.91	11.15	49.26	18.34
Relational Scoring w/o Criteria	29.67	15.38	61.93	14.99
Relational Scoring w/ Criteria	38.81	14.94	67.64	12.64
Kit-Build Concept Map	23.50	23.19	55.36	22.94

Table 3-3 *The g-coefficient for each manual method and the study of (McClure et al., 1999)*

	Current Study		McClure's
	Reading	**Teaching**	
Structural Scoring	0.7520	0.9029	0.23
Relational Scoring w/o Criteria	0.8659	0.8540	0.51
Relational Scoring w/ Criteria	0.8874	0.9133	0.76

A comparison between the KB map's result and the reliable manual method's result is required for analyzing the validity, which is an overall evaluative judgment, founded on empirical and theoretical rationales, of adequacy and appropriateness of inferences and actions based on test score (Messick, 2005). In McClure's research, they investigated the validity by the correlation between the concept map scores from each manual method and the similarity measure of each learner-build map with the criteria map. The similarity measure of each learner-build map and criteria map was held as the reasonable scoring method. To investigate the validity of KB method, the Pearson's correlation was computed using the R programming language and the correlation value is shown in Table 3-4. Following the strength of the correlation from (Evans, 1996), the relational method with criteria map, which achieved the highest reliability score, has a very strong correlation with the KB map in both reading and teaching situations. This is because raters use the criteria map as a frame for their scoring, in a similar way to the teacher-build map used in the KB map. For the remaining methods, the results from the relational scoring without criteria map have a very strong correlation in the reading situation and strong correlation in the teaching situation. This is because the procedure of relational scoring without the criteria map is too wide for meaningful evaluation of the learner-build maps, which are constructed for checking the understanding following a specific teaching situation. The structural scoring has a strong correlation with the KB map in both situations, even though structural scoring scores the concept map by giving precedence to the structure of the concept map, which is a different approach compared to the KB map.

Table 3-4 *The correlations in scores between each manual method and the KB method*

	KB in Reading	**KB in Teaching**
Structural Scoring	0.7360	0.7360
Relational Scoring w/o Criteria	0.8532	0.7371
Relational Scoring w/ Criteria	0.8671	0.8165

Note: Calculated Pearson product correlations are statistically significant as indicated by p-value < 0.01

The results above suggest that the KB map can assess learners' comprehension of a topic as well as the manual concept map assessment methods. If the manual methods give a relatively high score to a learner, the KB map also has a high possibility of giving a relatively high score to the learner. In addition, learners who get a relatively low score from the manual methods, also have a high possibility of getting a relatively low score from the KB map. As indicated by the high correlation value, the KB map has validity, and is comparable to the manual methods, in identifying learners' comprehension for a topic and evaluating the concept map reasonably.

3.3.2 Results of Questionnaire

Two sets of questionnaires, one was for learners and the other was for raters, were used in this study. The questionnaires for learners were answered just after they completed all of their tasks. The results are presented in Table 5. From the learners' questionnaire analysis, learners who did not have existing knowledge about the learning material before obtained a good understanding of the content after reading. In addition, the learners could accept the instructor's interpretation clearly after they received an explanation in the teaching situation. When learners constructed their learner-build map by creating their own linking words, most of them concluded that they could represent their understanding adequately; similarly, users of the kit KB map were able to express their understanding appropriately. This summary suggests that the KB map is appropriate to use in supporting learners to express their understanding, and that it produces similar results to using the concept map where the linking words are created freely.

The raters' questionnaire included two types of questions. One type is general questions as shown in Table 3-5 and the other type is questions to compare the three manual methods as summarized in Figure 8. As shown in Table 3-6, all raters identified their familiarity with using the concept map and their understanding of the learning material as strong confident.

The results of comparison of the three manual methods by raters are illustrated in Figure 3-4. The values are calculated by averaging the given score from raters in each manual method. Raters were requested to give score from one to three points by ranking each scoring method following four criterions: hardness of division, use of memory, time taken, and reasonableness of score. In Figure 3-4, the structural scoring was the hardest assessment method, because the rater had to decide on the suitability of each hierarchy and crosslink. (McClure et al.; 1999) concluded that it made high complex cognitive when the raters tried to compare the quality of many maps. Conversely, it was easiest to use the relational scoring

with criteria map since the criteria map could be used as a guide for scoring. For the cost of scoring, the raters noted that the structural scoring and the relational scoring without criteria map used their memory load and time more than the relational scoring with criteria map. This was because of the difficulty in thinking about the learner-build map structure and recalling how previous learner-build maps were scored. For this challenge, the criteria map can help the scoring of the learner-build map by using the relational scoring with the criteria map. In the final question, the raters were requested them to rank the most reasonable method in their opinion. The relational scoring with criteria map achieved the highest rating. This ranking corresponds with the comparison between six concept map assessments by (McClure et al.; 1999). Hence, the strong correspondence between the KB map and the relational scoring with criteria map confirms that the propositional level with exact matching of the KB map has validity for assessing the efficiency of learning and the KB map can be used as an alternative automatic method for assessing the concept map.

Table 3-5 *A part of the learners' questionnaire*

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Learners know about concept map before	9%	14%	9%	55%	14%
Learners know about material before	18%	27%	9%	41%	5%
Learners can represent their understanding by using Cmap Cloud	0%	5%	18%	73%	5%
Learners can represent their understanding by using KB map	0%	5%	0%	36%	59%

Table 3-6 *A part of the raters' questionnaire*

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I am familiar to use concept mapping	0%	0%	0%	75%	25%
I understand the article of the experiment	0%	0%	0%	25%	75%
For the Novak & Gowin structural scoring, - It is hard to evaluate the hierarchy of concept map	0%	25%	0%	50%	25%
- It is hard to evaluate the cross-link	25%	25%	25%	0%	25%
For the McClure & Bell relational scoring without master map - It is hard to score meaning of each proposition when I do not have a guide	0%	75%	25%	0%	0%
For the McClure & Bell relational scoring with master map - It is hard to score meaning of each proposition when I have a guide	25%	50%	0%	25%	0%
- I hesitated to score when the master map is provided	25%	50%	0%	25%	0%
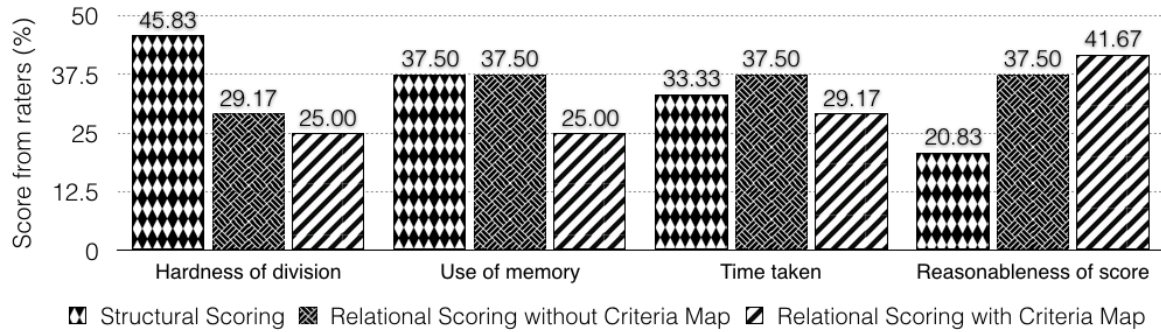
Figure 3-4 *A part of the score from the raters' questionnaire*

3.4   Chapter Summary

This study investigates the validity of the KB map assessment in terms of its ability to identify the efficiency of learning reasonably when it is compared with the well-known reliable manual methods. The objective of the experiment wants to show that the provided components of KB map do not affect learners when they tried to express understanding and the KB method can identify level of learner's understanding via concept map almost same level with the manual methods. An experiment was designed as a case study to compare the KB map assessment with three manual concept map assessment methods in reading and teaching situations. Selected manual methods contained structural scoring, (which investigates the composition of the concept map straightforwardly), relational scoring without the criteria map, and relational scoring with the criteria map. The relational scoring gives precedence to the meaning of propositions and is reasonable for evaluating understanding from a concept map, but requires expert checking and significant time input for scoring. These manual methods provide flexible and meaningful concept map assessment, and their reliability is widely accepted. However, they are inconvenient due to the limited class time that instructors have to complete a unit of instruction. In this study, the KB map was compared with the manual methods to test the assumption that the KB map has validity for identifying the efficiency of learning. From this study, the results show a strong and significant correlation between the KB map and the manual methods in both the teaching and reading situations. The KB map has the highest correlation with the relational scoring with criteria map, achieving the most reliability score (g-coefficient) in both learning situations. Moreover, the learner-build map scores of the KB map were similar to the manual methods. Based on these results, it is one of evidence, which can suggest that the validity of the KB map assessment is comparable to the manual assessment methods.

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COLLABORATIVE USE FOR SHARING UNDERSTANDING

Summary: In this chapter, a collaborative use of a Kit-Build concept map (KB map) called "Reciprocal KB map" is proposed. In a Reciprocal KB map for a pair discussion, at first, the two participants make their own concept maps expressing their comprehension. Then, they exchange the components of their maps and request each other to reconstruct their maps by using the components. The differences between the original map and the reconstructed map are diagnosed automatically as an advantage of the KB map. Reciprocal KB map is expected to encourage pair discussion to recognize the understanding of each other and to create an effective discussion. In an experiment reported in this paper, Reciprocal KB map was used for supporting a pair discussion and was compared with a pair discussion which was supported by a traditional concept map. Nineteen pairs of university students were requested to use the traditional concept map in their discussion, while 20 pairs of university students used Reciprocal KB map for discussing the same topic. The results of the experiment were analyzed using three metrics: a discussion score, a similarity score, and questionnaires. The discussion score, which investigates the value of talk in discussion, demonstrates that Reciprocal KB map can promote more effective discussion between the partners compared to the traditional concept map. The similarity score, which evaluates the similarity of the concept maps, demonstrates that Reciprocal KB map can encourage the pair of partners to understand each other better compared to the traditional concept map. Last, the questionnaires illustrate that Reciprocal KB map can support the pair of partners to collaborate in the discussion smoothly and that the participants accepted this method for sharing their understanding with each other. These results suggest that Reciprocal KB map is a promising approach for encouraging pairs of partners to understand each other and to promote the effective discussions

4.1   Introduction

Collaborative learning is an active teaching and learning strategy, which has been utilized in elementary, secondary, and higher education. It can contribute many advantages including improvement of interpersonal skill, development of critical thinking, problem solving, and

content mastery etc. Various studies can be used to confirm that such collaborative learning is beneficial (Johnson et al., 1998; Johnson & Johnson, 1999; Barkley et al., 2005). Therefore, the approach attracts many educators to utilize collaborative strategy in their classes and develop computer support system for increasing learning achievement. Discussion is also one of the collaborative techniques for communicating and sharing knowledge. Nunan noted that "A good give-and-take discussion can produce unmatched learning experiences as students articulate their ideas, respond to their classmates' points, and develop skills in evaluating the evidence of their own and others' positions" (Nunan, 1993). This demonstrates that discussion can support people to improve their skills. After reviewing several studies, Slavin concluded that "students who give each other elaborated explanations are students who learn most in cooperative learning" (Slavin, 1996).

Nevertheless, it is not common for a learner to give an explanation in an actual class. In Mercer's studies, he categorized talk in classroom discussion into three types, namely, exploratory talk, cumulative talk, and disputative talk (Mercer, 1996). He claimed that exploratory talk reveals the reasoning which is valuable for discussion. In addition to Mercer's research, the value of exploratory talk also was confirmed, in terms of its ability to facilitate reasoning in social contexts and to lead to the generation of new knowledge and understanding (Barnes, 1999; Rojas-Drummod et al., 2013; Webb & Treagust, 2006; Mercer & Dawes, 2008; Knight & Mercer, 2015; Haiyan, 2015). However, from Mercer's observations (Mercer et al., 1996; 2004), the exploratory talk is rare in classroom discussion.

The Kit-Build concept map (KB map) is a framework to realize automatic concept map assessment (Hirashima et al., 2011; 2015). Instant and automatic assessment of a learner-build concept map, realized in this framework, is referred to as the "Kit-Build method" (KB method). In this framework, the set of concept map's components which is called "kit" are made by decomposing a concept map that is built by a responsible teacher. This map is called the "teacher-build map". The responsible teacher is requested to build the teacher-build map as a criterion to assess a learner's comprehension for a specific topic or teaching. Then, a learner is requested to build a concept map to express his/her comprehension on the topic. Because all components of the learner-build map are the same as the teacher-build map, an automatic assessment of a learner-build map is realized by comparing the learner-build map with the teacher-build map. KB map and assessment methods have already been practically used in classrooms in various schools, for example, in science learning in elementary schools, geography in junior high schools, the learning of English as a second language, social science and computer science in university. Even KB map assessment method is an automatic assessment, it was examined the validity for evaluating learners' understanding (Wunnasri et

al., 2017; 2018). This investigation can suggest that KB map can support learners to express their understanding suitably.

This paper proposes a collaborative use of KB map called "Reciprocal KB map", which aims to encourage sharing understanding of each other in pair discussion. Moreover, to encourage the participants make their discussion actively is also in the expectation. In Reciprocal KB map for a pair discussion, at first, the two participants of the pair discussion make their own concept maps expressing their comprehension each other. Then, they exchange the components of their maps and request each other to reconstruct their maps by using the components. The differences between the original map and the reconstructed map are diagnosed automatically as an advantage of KB map. Reciprocal KB map is expected to encourage pair discussion to recognize the understanding of each other and to create an active effective discussion. In this paper, the results of an experiment where a pair discussion with Reciprocal KB map were compared with a pair discussion with traditional concept map. The comparison is analyzed in three viewpoints following: a discussion score, a similarity map score and questionnaires.

4.2   Related Works

4.2.1 Types of Talk

The analysis of classroom talk has received much attention in recent years. According to Mercer's proposed three types of talk (Mercer, 1996), as mentioned above each type of talk has a specific and different characteristic, and these can be created classroom discussion. The definition of exploratory talk reflects its positive aspects. The talk has to be constructed with each other's ideas, include joint consideration, give reasoning, and contribute to critical knowledge. This category of talk contributes to efficiency for learning and reasoning. Cumulative talk can be constructed from a common knowledge by accumulation. It is not as valuable as exploratory talk, but it is still part of collaborative talk. Disputative talk is the least valuable for achieving good discussions. There is a lot of disagreement in such talk and the atmosphere becomes competitive rather than co-operative. The concept of these three types of talk is accepted widely. Many researchers have confirmed the value of exploratory talk for encouraging critical thinking, reasoning and problem posing skills. However, in an actual class, it is rare to achieve exploratory talk from children in a discussion. Hence, one way to promote the quality of discussion is to focus on increasing the chance of reaching exploratory talk.

4.2.2 Collaborative Learning in the Classroom

In a collaborative knowledge-building process, a step where collaborators share others' understanding is very important (Stahl, 2000). We aim to apply KB map in the shared understanding step. Each collaborator has to adjust their perspectives and awareness of the others' understanding, even if they do not agree with the others' thinking. To make a shared understanding, several collaborative learning approaches were investigated. Advantages of collaborative learning are proposed in many researches, including increased measures of achievement, higher-level reasoning, increased frequency of new ideas, and situational transfer (Johnson et al, 1988). Additionally, a theory proposed by Resta and Laferriere, maintained that the social context can enhance creativity and learning (Resta & Laferrière, 2007).

Concept map were proved that it can help learners to significantly reduce their learning cognitive load because the concept map assists in the integration of knowledge and facilitates learners in their independent learning and thinking (Hu & Wu, 2012). Due to these characteristics, the concept map is used to organize and represent knowledge extensively. To make the concept map helps learners to aware of and reflect on their understanding and misunderstanding (Horton et al., 1993). However, most of the concept mapping studies concentrated on construction concept map by individual. Several studies have shown that to use concept mapping as a group task could receive significant learning gains and the learning outcomes were related to the quality of student's interaction (Boxtel et al., 2000). In study of (Boxtel et al., 2002), the collaborative concept mapping was used to provoke and support their physics discourse. They requested pairs of students to construct concept map by using their provided concept list. The results showed that the collaborative concept mapping task could assist students in taking more responsibility for their own learning during the course and it encouraged students to use language for thinking and reasoning together.

Hence, to encourage the quality of discussion among collaborators, we focus on the collaborative approaches that emphasize shared understanding. Reciprocal teaching (Palincsar, 1988) is an approach which deals with a summarization of understanding. This collaborative approach requests collaborators to participate in four roles that contain summarizing, questioning, clarifying, and predicting. These four roles really suit the discussion situation which aims to share understanding. Summarizing is a way to help collaborators to reconsider their understanding using for example, short-notes, mind maps,

and concept maps. Hence, we can properly apply summarization with KB map because it uses the concept map as a representation of understanding. After summarizing, the next role of collaborators is questioning. This role requires collaborators to think about the topic and forces them to identify areas where they are confused and require clarification. Once collaborators have questions in their mind, the role of clarifying encourages them to point out confusing areas and to clarify these. The predicting role is a more advanced stage for contributing collaborative knowledge. The collaborators have to send out their idea regarding what can happen next in the comprehension that they have just learned. They have to utilize their imagination to think ahead. However, this last role, predicting, is not contained in our current approach, the aim of which is to encourage shared understanding. However, it is necessary for the next step which involves producing a creative idea from collaborative knowledge.

4.3 Procedure of Reciprocal KB map and the Preliminary Experiment

In line with the objective to show that KB map can be used to achieve a productive discussion, we designed the experimental procedure. Firstly, participants were required to summarize their understanding and represent it in the form of the concept map by using the provided components. In this experiment, 12 labeled concepts, which relate to a reading article, were provided for all participants. This method which provides a concept list to learners is a regular strategy for limiting the scope of content (Novak & Gowin, 1984; McClure & Bell, 1990). Next, the participants were expected to formulate questions on the parts that they could not understand. Participants were then required to ask or find the answers to their questions during the pair discussion. Lastly, they had to think about the understanding that they got from asking questions and discussing. This experimental procedure was designed answer two research questions:

1) Could KB map be utilized for sharing understanding with each other?

2) What is the difference between discussions that use a traditional concept map and those that use Reciprocal KB map?

4.3.1 Reciprocal Kit-Build Concept Map

The different procedures between the usual KB map and Reciprocal KB map are shown in Figure 4-1. In the usual KB map, a teacher constructs a concept map reflecting ideal

understanding of a topic. This concept map is called teacher-build map, and then the system generates the kit by decomposing the teacher-build map. The kit is provided for the learners and they are requested to reconstruct a concept map by using the kit. In the framework of KB map, because the reconstructed map is also composed of the same components with the original one, the reconstructed map is automatically diagnosed by comparing with the original map. The result of the comparison is also represented as a map and it is called comparison map. In the comparison map, the different parts between the two maps specify the different understanding between the teacher and learner, and then, the same parts specify the same understanding between the teacher and learner. Based on the results the teacher gives feedback to the learners.

On the contrary, in Reciprocal KB map, two equal participants summarize their understanding in the form of the concept map at first, and then, their maps are decomposed to generate kits. Therefore, two maps and two kits are generated. The kit of a participant is provided for another participant (partner), and then, the partner is requested to reconstruct a map by using the kit. Therefore, two original maps and two reconstructed maps are generated. In the diagnosis phase, two comparison maps are generated. The participants are promoted to discuss their same/different understanding based on the two comparison maps that are provided by the KB map system.
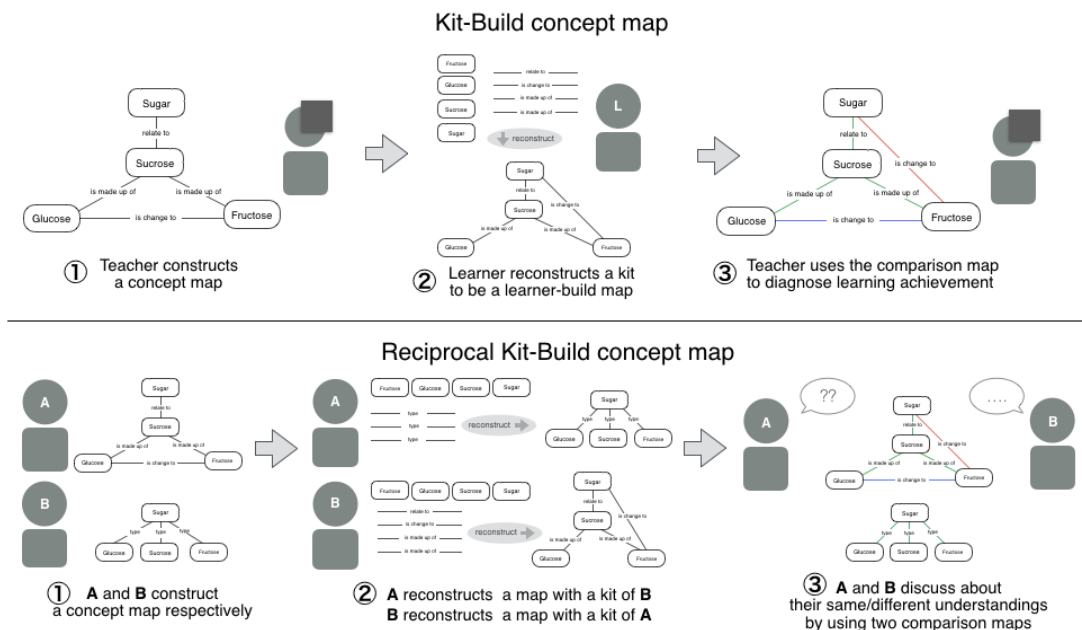

Figure 4-1 *Comparison of procedure between usual KB map and Reciprocal KB map*

4.3.2 Participants

The participants in this study were university students who were categorized by language into three groups. These three groups contained 16 international students who possessed a good level of English, 14 Japanese students and 48 Thai students. The total number of participants was 78 students who were volunteers from engineering fields. They were given introductory training in concept maps before participating in the experiment. From these 78 students, they were divided into two groups as the Normal Concept Map (NCM) group to serve as a control group and the Reciprocal Kit-Build (RKB) group as the experimental group. The group division is shown in Table 4-1.

Three graduate students, who were familiar with the use of the concept map and understood the content of the experiment material well, were assigned as raters. They were responsible for scoring discussion and concept maps in their own expert/native language. Hence, one rater was assigned to scoring the concept map and analyzing the conversations of the learners for each of the language groups of English, Japanese, and Thai. The procedure of the concept map assessment method was explained to the raters and they were required to study the procedures carefully before scoring the discussion and concept maps. In this study, the English article "Hurricane" (ReadWorks, 2017), which uses common explanatory words, was chosen for the learning process so the participants could understand it without bias. An English concept list, which contained 12 concepts, was prepared. These were translated into Japanese and Thai by native speakers that could use and understand English well.

Table 4-1 *The numbers of student pairs in the experiment*

	NCM group	RKB group
International students	4 pairs	4 pairs
Japanese students	3 pairs	4 pairs
Thai students	12 pairs	12 pairs
Total of pairs	19 pairs	20 pairs

4.3.3 Procedure of Preliminary Experiment

The concept mapping tool was developed based on an original KB map and new functions were added for supporting the pair discussion. An overview of the experimental procedure is illustrated in Figure 4-2.
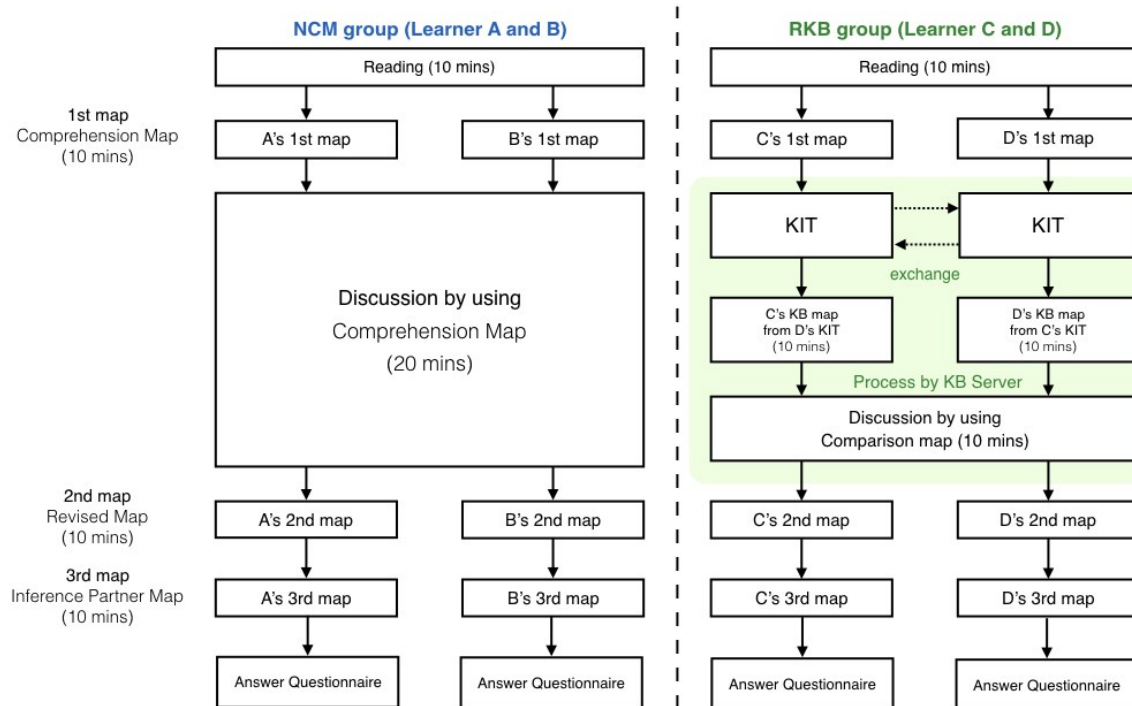
Figure 4-2 *Experiment Procedure*

The experimental procedure of the NCM group

The participants received the paper based article and they were allowed to underline and take short notes on the paper. After reading for 10 minutes, they had to construct the concept map by using the provided concept list in 10 minutes. In this step, they could freely create the linking words for specifying meanings of the relationships. The concept map constructed in this step is called "Comprehension Map". After the participants had uploaded the concept map to the server, they were paired with other students randomly. They were then requested to discuss their understandings between each other, including why they thought differently. The participants in the NCM group were given 20 minutes for discussion which they could terminate at any point.

After the discussion step, they had to construct a concept map from the concept list in 10 minutes, but this time they had to construct the concept map following their understanding after the discussion. The concept map in this step is called "Revised Map". When they had completed the second concept map, they were requested to construct the last concept map in 10 minutes, which had to be constructed following their partner's understanding from their viewpoint that they had obtained from the discussion task. This map is called "Inference Partner Map". After they finished the last concept map, they were asked to complete the questionnaire.

The experimental conditions for RKB group were the same as the NCM group. The participants had 10 minutes for reading the article and they could also write on or underline the paper. They had to construct the concept map by using the provided concept list and they could create the label for each relationship freely in 10 minutes, in the same way as the NCM group. After they completed their Comprehension Map, they were paired with other students randomly and their concept maps were decomposed to form the "kit", which contained a list of concepts and a list of relation lines with linking words. After the kits were generated, these decomposed components were sent to the partner of the kit's owner. The participants had to use the kit to construct the concept map following their understanding in 10 minutes. Then the participants had 10 minutes to discuss with their partner any points where they had the same or different understandings, as well as the reason for any different understandings. In this discussion, they were provided an overlay of each other's maps, called "Comparison Map", for facilitating their discussion. The comparison map can represent three types of error link, namely, a lacking link, an excessive link, and a leaving link.

As with the NCM group, after the discussion, they had to construct the Revised Map and the Inference Partner Map, for which they were allowed only 10 minutes for each step. They then had to also complete the questionnaire.

4.3.4 Preparation before Analysis

To evaluate the similarity between two concept maps, the relational concept map assessment method (the relational scoring) is applied. This is a well-known manual concept map assessment method was claimed to have the highest reliability compared to the other five manual methods among those considered reliable (McClure et al., 1999). This method scores the concept map by checking the possible relationship between each proposition, the suitability of the label between concepts of the proposition and the compatibility between label and the direction of the arrow or hierarchy between two concept maps. Hence, it can illustrate the similarity between two maps (McClure & Bell, 1990). The raters awarded scores between zero and three points for each proposition based on the suitability of the meaning of the proposition. The relational scoring is proper to use to compare how the same/different meaning of each proposition between two concept maps. Because the procedure of this scoring method pays the attention of scoring to the meaning of linking words in propositional level, the relational scoring was selected to check the similarity of concept map of two collaborators in this study.

In this experiment, we gathered the results of three groups of participants, that is, English used, Japanese used and Thai used group. In order to confirm that the understanding before discussion of each group was not much different, the relational scores that were calculated as the similarity between Comparison Map of each pair. The result of ANOVA showed that their differences were not statistically significant. So, we combined the three groups together in the analysis of the experiment. The average of relational scores of each language groups were represented in Table 4-2. Based on this result, we combined the three groups together in the analysis of the experiment.

Table 4-2 *Average relational scores between the Comprehension maps of each pairs*

Language of Group	The number of participants	Average score	Variance
English students	16	31.72	12.97
Japanese students	14	40.04	13.97
Thai students	48	30.87	21.23

Note: The differences between three language groups in the scores was analyzed by using ANOVA single factor, and the result was not significant (p-values = 0.27).

4.3.5 Questionnaire

The questionnaires were prepared for the NCM and RKB groups separately to examine their opinion about the discussion using the traditional concept mapping and Reciprocal KB map. These questionnaires also asked the participants about their activity during the discussion. These questions request the participants to evaluate both themselves and their partner. Lastly, the participants had to conclude their discussion by identifying where their understanding was the same and where it was different. If they had a different understanding, they had to give the reason, based on their discussion.

4.4 Experiment Results

4.4.1 Discussion Score

The experimental results show that discussions with the traditional concept map and with Reciprocal KB map are different. The discussion score was evaluated from the Comprehension Map and the content of discussions from each pair of participants. The raters had to match each proposition with the conversation in the discussion, and then categorize that conversation to each type of talk (Mercer, 1996) and the part of actual conversations in the experiment is displayed in Figure 4-3. The raters had to consider each proposition of the

concept maps and give a discussion score for each type of talk on the mentioned proposition. The raters counted a conversation as exploratory talk when the discussed cooperatively and shared the reasons for their statement/answer. For the cumulative talk, the raters counted conversations where the participants tried to share their understanding but they did not give a reasonable answer. Conversations where the participants just made their own decisions or which led to more competition than cooperation, were classified as disputative talk. Lastly, talk where the participants only read to their partner were scored as "Non-Contributed Discussion Talk." For these, the participants did not receive any critical discussion points.

Exploratory Talk	Cumulative Talk	Disputative Talk
B: Why did you connect "Hurricane makes Landfall"? A: Hmm, because it move to the land. That is landfall, isn't it? B: Huh, first I think it is land .. soil falling. I connect "Hurricane cause Landfall". A: I think it means move to the land because if it means land falling, we can use "Mudslides" concept. B: I see. Maybe it is my wrong translation. Thanks!	A: I connected Hurricane with Landfall by using "makes" relation. How did you connect them? B: I connect with "cause". A: Sounds good. It is possible.	A: I connected "Hurricane makes Landfall". How's about yours? B: I linked Hurricane and Landfall by "cause". A: Why? That's wrong. B: Hmm, why do you say like that? A: Because it's wrong. Hurricane makes Landfall at USA. B: You have to explain why do you think like that. A: It is already written in the article.

Figure 4-3 *Conversations in each type of talk on the participant's proposition*

Following these criteria, the results of the discussion score for each group are illustrated in Figure 4-4. These pie graphs show the difference between the ratios of each type of talk from each participant group. In the experiment, most of the participants from the NCM group read their concept map for discussion. Their partner just checked the same and different parts and then asked a few questions and finished the discussion. Therefore, this process can produce all types of talk, but the Non-Contributed Discussion talk was more dominant than the others. This situation shows that the concept map can help participants to represent and organize their understanding, but it requires more features to encourage the participants to think about their propositions more deeply than just reading them. On the other hand, Reciprocal KB map requests that the participants reconstruct the kit of their partner, so they have to think deeply about their partner's understanding. Even if they cannot connect their

partner's kit well, they can ask questions of their partner during the discussion. Because they have questions in their mind during the connecting of the kit, their questions have an inquiring characteristic regarding the form of the kit such as "Why did you connect like this? Why can I not connect your proposition? How do you think about this proposition?" In addition, during the connection of the kit, participants can arrange their questions in order to clarify their confusion.
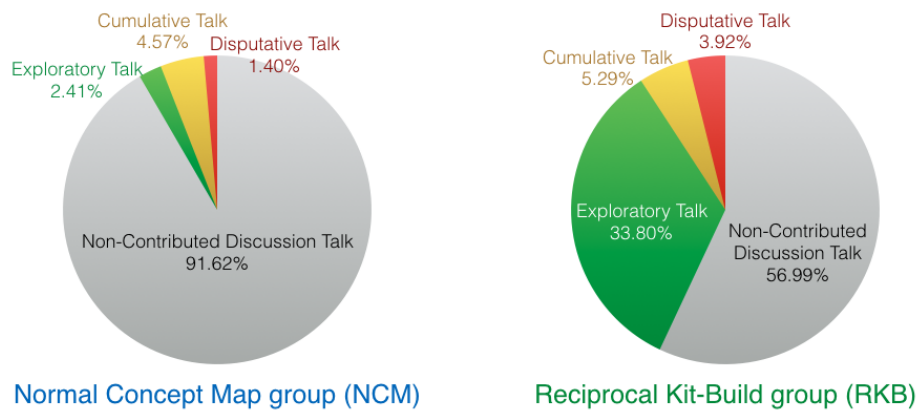
Figure 4-4 *The results of discussion score*

In discussion phase, the comparison maps were displayed to the participants in RKB group. They could find the same- and different- understanding by using the comparison maps. Questions or explanations for the different parts in the comparison maps satisfy the conditions of exploratory talk. When the participants tried to explain their own conceptions, they gain a greater conceptual clarity for themselves (Damon & Phelps, 1989). Then, when participants had confidence about the different parts, and did not agree to change them, mentions about the different parts satisfy disputative talk. In contrast, in NCM group, participants were required to find such different parts from their concept maps by themselves. Regarding to cumulative talk, it appears when the participants easily agree their partner's understanding and did not request the reason. In RKB group, because the same understanding parts were clearly displayed on Comparison Maps so they did not much request to confirm these agreement parts. We think these are reasons that explanatory talk and disputative talk were more promoted and cumulative talk was not promoted in RKB group.

In terms of the number of proposition that the participants chose to discuss, the participants in the NCM group mentioned their proposition 255 times which was 34.45% (S.D. = 20.13) of the total number of propositions and they used an average discussion time of 6 minutes (S.D. = 3.30) from the 20 minutes provided, with many silent gaps during the discussion. The participants in RKB group brought up their proposition for discussion 347

times, which was 41.53% (S.D. = 16.18) of the total number of propositions and they used an average time of 8.7 minutes (S.D. = 1.59) from the ten minutes provided. This evidence suggests that Reciprocal KB can support the participants in discussing the topic smoother compared to the traditional concept map because during the construction of their partner's kit, they had to think about the kit and their partner's understanding before formulating questions in their mind.

This behavior affected their discussion. The participants in the RKB group gave the questions to their partner regularly. They asked about the reason for their partner's proposition construction and answers were given in the form of an explanation. On the other hand, the participants in the NCM group tried to read the propositions to each other and they assumed that their partner could understand them. Since they used a short amount of time for finding their interesting proposition, it was rather difficult for them to achieve a smooth discussion. In addition, there were a lot of different propositions which they could not notice and they could not articulate the reasons for different understandings between each other.

From the different types of talk that the participants from the NCM and RKB groups produced, we can conclude that the Reciprocal KB map can encourage the participants to produce more exploratory talk, which is effective for discussion, compared to the use of the traditional concept map. This result corresponds to the second research question which was related to investigating the differences between discussions that used the traditional concept map and discussions that used Reciprocal KB map.

4.4.2 Similarity Map Score

During the experiment, the participants in the two groups were requested to construct the concept map three times. The first correspond to the Comprehension Map, which represents their understanding before discussion. The second was Revised Map, which represents their understanding after discussion. The last map was Inference Partner Map, which was constructed following the understanding gained from their partner. These three maps were paired and were scored by the relational scoring. The average score from each paired map and each group is represented in Table 4-3.

From the relational scoring, all participants in both the NCM and RKB groups had the same understanding after reading the article with no significant differences. After discussion, the participants in the RKB group could construct the same concept maps as their partner more than the participants in the NCM group, with this difference close to being statistical significant. This shows that the discussion can change some parts of their understanding to achieve a joint viewpoint. In addition, the participants in the RKB group constructed their

Inference Partner Map to be the same as Revised Map of their partner more effective than the participants in the NCM group, with a statistically significant difference. These similarity map scores correspond to the first research question. This illustrates that Reciprocal KB map can encourage the participants to recognize their partner's understanding better than the traditional concept map. This ability will be a strong advantage for the next step of creating collaborative knowledge, as partners that can understand each other can better generate collaborative knowledge.

Table 4-3 *Average relational score of each type of concept map*

Average Score	NCM Group	RKB Group	
Comprehension Map *and* Comprehension Map of their partner	29.39 (S.D.=16.69)	35.83 (S.D.=20.30)	
Revised Map *and* Revised Map of their partner	49.04 (S.D.=32.08)	61.85 (S.D.=26.56)	+
Inference Partner Map *and* Revised Map of their partner	46.57 (S.D.=29.52)	61.15 (S.D.=22.16)	*

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

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

4.4.3 Interpreting Questionnaires

Tools of discussion

In this experiment, two types of concept mapping tools were provided for participants. Questions in a questionnaire for a tool that a participant used are shown in Table 4-4. In the results, the majority of participants in the both groups accepted the concept map (that is, normal concept map in NCM group and Reciprocal KB map in RKB group) as a useful tool to express their understanding and to promote their discussion. We could not find the difference between both maps as a way to express understanding.

In addition, from the open-ended question that requested them to share their opinion on this discussion method, most participants from NCM group noted that the concept map was a suitable tool for representing their understanding allowing them to further understand their partner's viewpoint. Some participants said it was harder to understand their partner's concept map compared to reading text and the improper propositions made them confused. It was also noted that the experimental process took a very long time.

The participants in the RKB group noted that Reciprocal KB map was a new thing for them. They stated that reconstructing the kit to concept map of their partner was fun and like playing a game, and that they could understand each other better from the discussion. Additionally, they stated that the 10 minutes provided time was not enough for the discussion. Some people found that it took a long time to create the concept map when they were

requested to construct the Revised Map and Inference Partner Maps. However, these two maps were used only to confirm the assumptions in the experiment and are not required in the general application of the approach.

**Table 4-4** *A part of the questionnaire regarding tools of discussion*

| 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

Collaborating during discussion

In the questionnaire, participants were also required to check the actions during the discussion of both themselves and their partner. A total of 31.25% of participants from the NCM group evaluated themselves and their partner in the same way as not breaking the interim silence by introducing a possible topic for consideration. This means they did not discuss a topic continuously. In contrast, most of the participants from the RKB group identified that they and their partner tried to explain their understanding to each other clearly and tried to introduce their interesting or confusing topic as much as they could, but the time provided was not enough. The parts of results from self- and peer assessment questionnaire on collaboration during discussion is illustrated in Figures.4-5 and 4-6 for the NCM and RKB

groups, respectively. Moreover, in the part of the questionnaire which asks about identification of the same/different understanding, the participants from the NCM group recognized areas where they had same understanding as their partner but they had some confusion about where their understanding differed. For example, the NCM group participants filled out the different understanding field in the questionnaire but their partner completed that topic in the same understanding field. Additionally, they could not give clear reasons for their different understandings. This situation may indicate that the participants were still confused after the discussion. In contrast, the RKB group participants could identify the same/different understanding and they could give reasons for this. In addition, the pairs of participants who changed their proposition on the map tried to explain the reason why they changed their understanding.
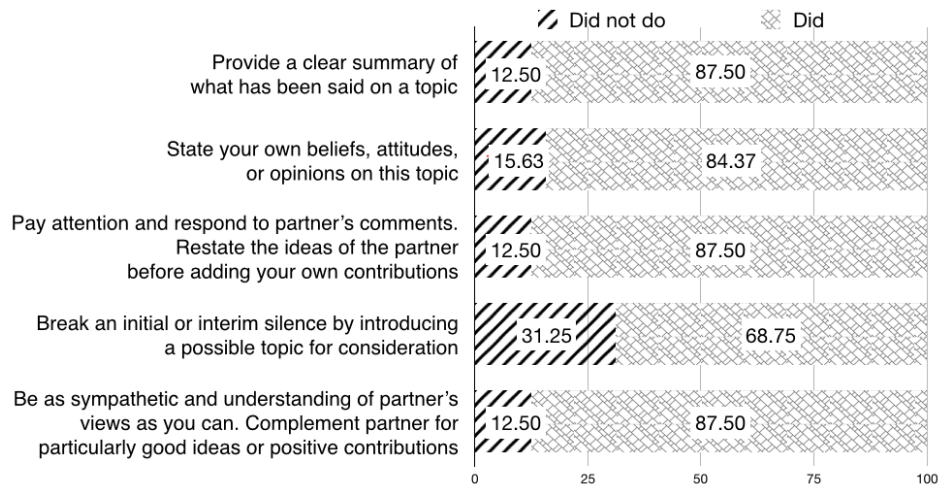
Figure 4-5 *A part of the questionnaire about collaboration of NCM group*
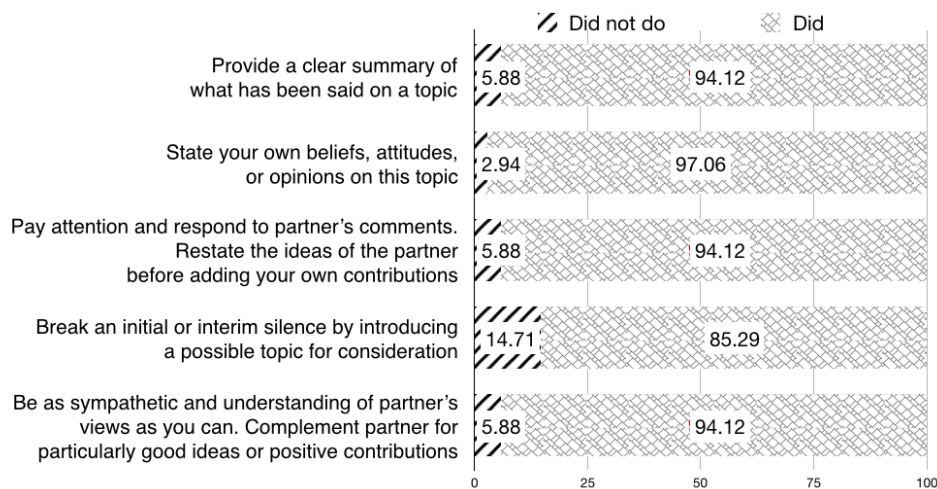
Figure 4-6 *A part of the questionnaire about collaboration of RKB group*

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From the experimental results, we can answer the two research questions posed in Section 3. The similarity score between Inference Partner Map and Revised Map of their partner indicates that Reciprocal KB map can support the participants in understanding each other. Additionally, the difference between the ratios of each type of talk in the NCM and RKB groups can answer the second research question, related to the difference between discussions using the traditional concept map and Reciprocal KB map. The participants from the RKB group who had to reconstruct their partner's kit were encouraged to produce exploratory talk more than the participants from the NCM group. These advantages over the traditional concept map can contribute to generating high quality collaborative knowledge through better understanding of each other.

4.5   Chapter Summary

Kit-Build concept map (KB map) is an automatic concept map assessment framework which is utilized in the form of a learning task or exercise for checking learners' comprehension of a topic that they have already learned. Usually, it is used for confirming understanding between a teacher and learners in a class and it has previously been investigated in terms of its ability to support learners in expressing their understanding. This research proposes the utilization of KB map with a collaborative approach for encouraging shared understanding in pair discussion. The experiment was designed to compare discussions using a traditional and Reciprocal KB concept map. The results are separated into three parts: (1) the discussion score, (2) the similarity map score, and (3) the questionnaire. For the similarity map score, the concept map of participants was evaluated for similarity using several viewpoints. The most important aspect is represented by the similarity between Inference Partner Map and Revised Map of their partner, which showed that the participants from the RKB group could recognize their partner's understanding better than the participants from the NCM group. This was because during reconstruction of the concept map using the provided components from Reciprocal KB map, the participants had to consider their partner's understanding more deeply than just reading the concept map or just checking the same/different understanding, as was the case for most participants from the NCM group. The similarity map score and the results of the questionnaire correspond to the first research question. They indicate that the Reciprocal KB map can contribute to pair discussions for sharing understanding. Additionally, in the discussion score, the participants from the RKB group produced more exploratory talk, which is valuable for contributing to effective discussion, compared to the

participants from the NCM group. Most of the participants in NCM group just read their concept map to check their understanding with their partner. Therefore, the discussion score answers the second research question and indicates that Reciprocal KB map is useful for encouraging pair discussion and producing the active effective discussions which can contribute to creating high quality collaboration more effectively better than the traditional concept map. However, because the topic of discussion is guided by the kit, the creative discussion might be reduced. Evaluation of Reciprocal KB map from viewpoint of creativity is our important future work.

CHAPTER 5

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CONCLUSION AND FUTURE WORK

5.1   Conclusion of the Study

Usually, KB map is used for confirming understanding between a teacher and learners in a class and it has not been investigated about the validation of concept map assessment method and the abilities to support learners in expressing their understanding. In the first study of this thesis aims to confirm that the validity of the propositional level exact matching of KB map can attain almost same level with the reliable manual concept map assessment. The results are confirmed by the high correlation value between the scores which were evaluated by the manual methods and the scored which evaluated by KB map method. In the experiment, the ability to express understanding when using KB map is also confirmed from the participants that they can use KB map for express their understanding without the disturbance from the provided components (Kit). Hence, the next step to reach goals of this studies is to design the collaborative use of KB map for sharing understanding in pair discussion. Firstly, the two participants of the pair make their own concept maps expressing their comprehension. Then, they exchange the components of their maps and request each other to reconstruct their maps by using these components. The differences between the original map and the reconstructed map are diagnosed automatically, called the comparison map, as an advantage of the KB map. The results of this study show the most of participants from Reciprocal KB can understand their partner's understanding well. In addition, the participants who used Reciprocal KB map make their discussion more active than the participants from NCM group. For the discussions which were created based on the Reciprocal KB map, they have the ratio of exploratory talk more than the discussion of the participants in the traditional concept map.

5.2   Future Works Direction

From the preliminary experiment of Reciprocal KB map, the procedure was confirmed that it encourages the participants to make high quality discussion smoothly actively and high

ratio of exploratory talk were created more than the participants who used the traditional concept map in their discussion. Nevertheless, the relation between the quality of discussion and the method by which they changed and shared their comprehension after discussing was not be investigated in this study. A deeper analysis of aspect is reserved for future work. Additionally, we will attempt to use Reciprocal KB map for practical application in a classroom, and to evaluate the products of discussion. The use of different topics and ages of collaborators is also an interesting focus for future work, in order to confirm the efficiency of Reciprocal KB map. In addition, to expand this research, Reciprocal KB map will be designed for supporting group discussion. After completing the supporting aspects for sharing understanding within pairs, we plan to promote collaborators to create creative discussion continuously. This next step of Reciprocal KB map will support its use in various discussion tasks.

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