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Auther(s)	Wunnasri, Warunya ; Pailai, Jaruwat; Hayashi, Yusuke; Hirashima, Tsukasa
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Reciprocal Kit-Building of Concept Map to Share Each Other's Understanding as Preparation for Collaboration

Warunya Wunnasri, Jaruwat Pailai, Yusuke Hayashi & Tsukasa Hirashima

Graduate school of Engineering, Hiroshima University, Japan

warunya,jaruwat,hayashi,tsukasa@lel.hiroshima-u.ac.jp

Abstract. Collaborative learning is an active teaching and learning strategy, in which learners who give each other elaborated explanations can learn most. However, it is difficult for learners to explain their own understanding elaborately in collaborative learning. In this study, we propose a collaborative use of a Kit-Build concept map (KB map) called "Reciprocal KB map". 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 concept 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.

Keywords: Collaborative Learning, Pair Discussion, Kit-Build Concept Map, Shared Understanding

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 that consist of an improving interpersonal skill, development of critical thinking, problem solving skill, content mastery and etc., and various studies can be used to confirm that the collaborative learning is beneficial [1-3]. Therefore, it is focused as an effective instructional medium and attracts many educators to utilize collaborative strategy in their classes and develop computer support system for increasing a learning achievement. A discussion is also one of the collaborative technique for communicating and sharing knowledge. NuNan [4] mentioned 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." This sentence demonstrates that the discussion can support people to improve their skills. From a reviewing of several studies, Slavin concluded that "students who give each other elaborated explanations are students who learn most in cooperative learning [5]."

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 [6]. 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 [7-12]. However, from Mercer's observations [13], exploratory talk is rare in classroom discussion.

The Kit-Build concept map framework (KB map in short) is one of the automatic concept map assessment methods that uses a teacher-build map to compare with the learner-build map by using exact matching at the propositional level. It is utilized in the form of a learning task or exercise for checking learners' comprehension of a topic that they have already learned [14, 15]. Following results of a previous study [16, 17], KB map can be used to express understanding and the automatic concept map assessment method can attain the same reliability and validity level as a typical manual assessment. Hence, we assume that KB map can be an effective instructional medium for sharing understanding. In this paper, we propose a collaborative use of KB map called "Reciprocal KB map", which aims to encourage sharing understandings with each other in pair discussion. In Reciprocal KB map for pair discussion, at first, 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, as an advantage of the KB map. Reciprocal KB map is expected to encourage pair discussion to promote shared understanding and to create effective discussion. In this paper, the results of an experiment where a pair discussion with Reciprocal KB map was used are compared with those of a pair discussion using a traditional concept map. The

comparison is analyzed using the following three metrics: a discussion score, a similarity map score and questionnaires.

2 Related Work

2.1 Collaborative Learning in Classroom

In a collaborative knowledge-building process, a step where collaborators share others' understanding is very important [18]. 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 [19]. Additionally, a theory proposed by Resta and Laferriere [20], maintained that the social context can enhance creativity and learning.

Hence, to encourage the quality of discussion among collaborators, we focus on the collaborative approaches that emphasize shared understanding. Reciprocal teaching [21] 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, the 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.

2.2 Kit-Build Concept Map and the Practical Use

The KB map is a framework to realize automatic concept map assessment [14, 15]. 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 components as the set "kit" are made by decomposing a concept map that is built by a responsible teacher. This map is called the "teacher-build map". The re-

sponsible 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 for the same topic or teaching. 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. Because of a page limitation, the figure of KB map procedure is represented in [16, 17] additionally. KB map and assessment methods have already been practically used in classrooms in various schools, for example, in science learning in elementary schools [22, 23], geography in junior high schools [24], learning English as a second language [25], and university-level social science and computer science [26, 27]. Even the KB map assessment method is automated, and the validity of this for evaluating learners' understanding has been confirmed previously [16, 17]. This investigation suggests that KB map can support learners to effectively express their understanding. Moreover, the diagnostic results from KB map can be utilized as a formative assessment tool for supporting teachers in designing feedback in their class effectively [28].

3 Research Methodology

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 related 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 [29, 30]. Next, the participants were required 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 were requested to think about the understanding that they got from asking questions and discussing. This experimental procedure was designed to 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?

3.1 Reciprocal Kit-Build concept map

In the usual KB map, teachers use it for checking learners' understanding about the topic that they have already learned. The teacher's expectation is constructed in the form of the teacher-build map, and then the system generates the kit. The kit is provided for the learner and they are requested to reconstruct it. After the learner-build maps are uploaded, the teacher gives feedback to learners based on the diagnosis results. However, procedure of Reciprocal KB map is different as Figure 1. It is designed for encouraging pair discussion to aid understanding of each other. Two conversational partners have to summarize their understanding in the form of the concept

map, and then their map is extracted as the kit. The kit is provided for their partner and they are requested to reconstruct it. Next, they have to discuss their understanding by using the comparison map that is generated by comparing the original concept map and the reconstructed map.

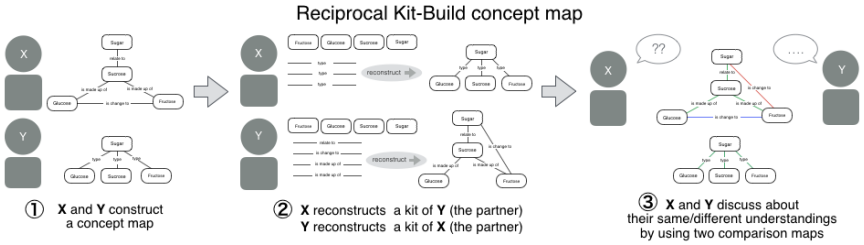

Fig. 1. Procedure of Reciprocal KB map

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. The participants were paired and divided into two groups. Thus, four pairs of international students, three pairs of Japanese students and 12 pairs of Thai students were grouped in the Normal Concept Map (NCM) group to serve as a control group. The participants in the Reciprocal Kit-Build (RKB) group served as the experimental group and this contained four pairs of international students, four pairs of Japanese students and 12 pairs of Thai students. All of the participants were given introductory training in concept maps before participating in the experiment.

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” [31], 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.

3.3 Experiment Procedure

Even though the 78 university students used different languages, they participated in the experiment under the same conditions, using the same experiment procedure, content, and concept mapping tool. 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 2.

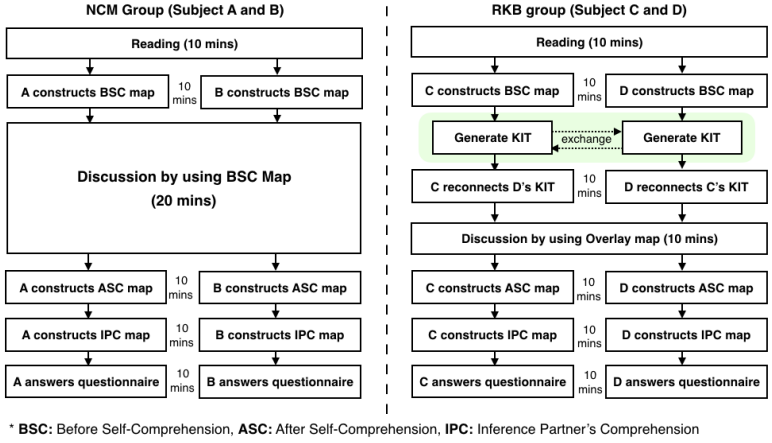

Fig. 2. Overview of the experimental procedure.

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 "Before Self-Comprehension Map" (BSC map) for the individual, and "Before Partner's Comprehension Map" (BPC map) for the partner's concept 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 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 "After Self-Comprehension Map" (ASC map) for the individual, and "After Partner's Comprehension Map" (APC map) for the partner's concept 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 the individual's understanding of their partner's viewpoint, which they obtained from the discussion task. This map is called "Inference Partner's Comprehension Map" (IPC map). After they finished the last concept map, they were asked to complete the questionnaire.

The experimental procedure of the RKB group

The experimental conditions for the 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 BSC 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 reasons for any different understandings. In this discussion, they were provided an overlay of each other's maps for facilitating their discussion. The comparison map can represent the links that the pair connected both same and different connections.

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

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 [32]. 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 [30]. 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. So the relational scoring was selected to checked the similarity of concept map of two collaborators in this study.

In this experiment, the results of all participants which contained three languages, (English, Japanese, and Thai), were combined for analysis. To confirm that before discussion these three group of participants are not different, the relational scoring was used to evaluate the similarity between the BSC and BPC map of each participant. The average of relational score of each language was represented in Table 1. These relational scores of three language groups were examined using ANOVA and the results showed the difference in the relational scores of these three language groups were not statistically significant, having a p-value = 0.2708. This means they had the same understanding in pairs not much different before discussion.

Table 1. The average relational scores between the BSC and BPC maps

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

Note: Calculated ANOVA are statistically *not* significant difference (p-value=0.2708)

3.5 Questionnaires

The questionnaires were prepared for the NCM and RKB groups separately to examine their opinion about the discussions 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, they 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 Experiment Results and Discussion

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 BSC 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 [6]. 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 pair 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 explain clearly or 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.

Following these criteria, the results of the discussion score for each group are illustrated in Figure 3. These 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 understand-

ing, 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.

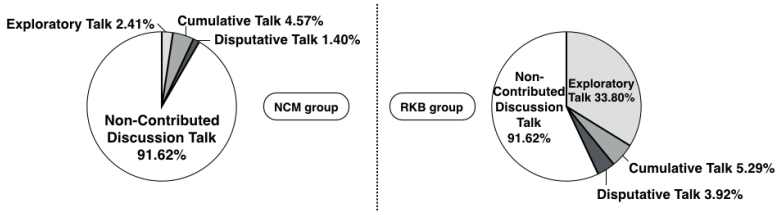

Fig. 3. The results of the discussion score.

Table 2. The average relational score of each type of concept map

	NCM Group	RKB Group
The number of mentioned propositions (props)	255 props from 770 props (33.12%)	347 props from 860 props (40.35%)
Average time of discussion	6 mins (S.D.=3.30) from 10 mins provided	8.7 mins (S.D.=1.59) from 20 mins provided

Table 2 suggests that Reciprocal KB can support the participants in discussing the topic more smoothly 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 choosing their proposition to discuss, 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 both 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.

4.2 Similarity Map Score

During the experiment, the participants in the two groups were requested to construct the concept map three times. The first corresponded to the BSC map, which represents their understanding before discussion. The second was the ASC map, which represents their understanding after discussion. The last map was the IPC 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 3.

Table 3. The average relational score of each type of concept map

Average Score	NCM Group	RKB Group	
BSC map *and* BPC map	29.39 (S.D.=16.69)	35.83 (S.D.=20.30)	
ASC map *and* APC map	49.04 (S.D.=32.08)	61.85 (S.D.=26.56)	+
IPC map *and* APC map	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)

BSC: Before Self-Comprehension, **BPC:** Before Partner-Comprehension, **ASC:** After Self's Comprehension, **APC:** After Partner's Comprehension, **IPC:** Inference Partner's Comprehension

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 IPC map to be the same as the APC map more effectively 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.

4.3 Results of Questionnaire

Tools of discussion

In this study, two types of concept mapping tools were provided for participants. The participants of both groups were provided the list of concepts and created linking words by themselves. The participants in the NCM group used their concept map as content for discussion. From the open-ended question that requested them to share their opinion on this discussion method, most participants 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 long time.

The participants in the RKB group noted that Reciprocal KB map was a new and interesting 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 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 ASC and IPC 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.

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 that 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. 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 the same understanding as their partner but they had some confusion about where their understandings 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 understanding. 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.

4.4 Summary of Experiment Results

From the experimental results, we can answer the two research questions posed in Section 3. The similarity score between the IPC and APC maps 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.

5 Conclusion and Future Work

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 the IPC and APC maps, 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 the 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 effective discussions which can contribute to creating high quality collaboration more effectively 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.

The results of this experiment confirm that the Reciprocal KB map can encourage collaborators to engage in high quality discussion and to share their understanding. However, 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 this aspect is reserved for future work. Additionally, we will attempt to use Reciprocal KB map for practical applications 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 continuous creative discussion. This next step of Reciprocal KB map will support its use in various discussion tasks.

Acknowledgements

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