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Preliminary Study on the Use of Reciprocal Kit Build for Collaborative Learning

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Abstract: Collaborative learning needs a careful instructional design to improve specific interaction that would trigger learning. Some previous studies show that concept map as a visualization tool is powerful to support learner to achieve a certain depth of discourse. Additionally, students also should prepare in their private workspace before creating a collaborative concept map to help them externalize and reorganize own knowledge. Difficulties appeared when students have to integrate their individual proposition with the group concept map. In this study, we use the Reciprocal Kit Build (RKB) approach to help students understand the partner's point of views and integrate it with his understanding. We measure the effect of proposed procedures on the students' learning performance based on the group map scores. Further, we also analyze how the dynamics appeared in the RKB comparison map reflected on the students' final group maps.

Keywords: collaborative concept map, kit build, collaborative learning, co-construction of knowledge

1. Introduction

According to Dillenbourg (1999), collaborative learning is a situation where interactions between people are predicted to occur that would trigger a learning mechanism. It is necessary to design an appropriate instructional method to improve the interaction by setting up an initial condition, specifying scenarios and rules to scaffold productive interaction and to monitor and regulate interactions (Dillenbourg, 1999). If properly designed, collaborative learning will be beneficial for students, regarding social, psychological, and academical benefits (Laal & Ghodsi, 2012). Moreover, collaborative learning promotes critical thinking and increases participation. It is also useful for developing learning communities and building positive attitudes (Laal & Ghodsi, 2012).

Collaborative learning requires supportive instruction to enrich the discussion among students by employing scenarios, scripts, roles, or mapping tools (Fischer, Bruhn, Gräsel, & Mandl, 2002). In particular, some previous studies recommended that concept mapping can foster a more intensive discourse between learners (Roth & Roychoudhury, 1993; Van Boxtel, Van Der Linden, Roelofs, & Erkens, 2002). Concept map as a representational tool in group discussion is useful to make group members' thinking visible and enable them to do an evaluation. Therefore, in this study, we choose the concept map as a supporting tool for discussion.

Some studies also emphasize the importance of individual preparation phase before creating a collaborative concept map by making a design for the concept map. Van Boxtel, Van Der Linden, and Kanselaar (2000) suggested that individual preparation create better learning outcomes and more exploration in the form of questions. Gracia-Moreno, Cerisier, Devauchelle, Gamboa, & Pierrot (2017) showed that individual preparation helps students to explain their ideas better when preparing the group map.

Individual preparation in a private workspace also has several challenges: students are reluctant to share their ideas in private workspace, and they encounter difficulties when integrating own ideas with the group ideas while constructing a group concept map (Gracia-Moreno et al., 2017). It may due to the students partially understand the perspective of others. Having a reasonably accurate idea about what other people know is essential to reduce miscommunication and perhaps embarrassment (Nickerson, 1999).

Wunnasri, Pailai, Hayashi, & Hirashima, (2018a) introduced Reciprocal Kit Build (RKB) as an approach to exchange ideas with partners in the forms of a concept map. In RKB, every student creates a concept map, and then reconstructs a map given partner's nodes and links. The system will display the similarities and differences between the reconstructed map and the initial map. The approach helps students to understand others' point of view and promote more effective discussions since they can focus only on the different ideas.

In this study, we adopt the RKB approach before students create a group concept map. We hypothesize that our approach may help students to reflect on their understanding, recognize the partner's understanding, and promote integration when they are composing a group map. The following research questions guide our study:

1. Based on the RKB procedures, to what extent students' learning achievements are improved?
2. How does the visualization of the comparison map in the Reciprocal Kit Build influences the students' performances?

2. Literature Review

2.1 Collaborative Concept Map

Fischer, Bruhn, Gräsel, & Mandl (2002) defined collaborative learning process into four stages: externalization of task-relevant knowledge, elicitation of task-relevant knowledge, conflict-oriented consensus building, and integration-oriented consensus building. They explained that the concept map as a visualization tool is aligned with those processes as follows:

- externalization of abstract concepts and the relations between concepts
- representation in the form of concept map support students to detect missing explanation, so that partner will trigger more question and leads to elicitation of knowledge
- concept map reduces the ambiguity of utterances, and different views can be detected easily resulting in cognitive conflict and the negotiation of meaning to reach consensus building

Correia, Infante-Malachias, & Godoy (2008) also recommended a concept map as a powerful visualization tool for representing knowledge and used to create mental models explicit for sharing and revising ideas. By using a concept map, participants can visualize, interpret and organize their ideas, before starting consensus building.

Gracia-Moreno et al. (2017) assessed whether the use of simultaneous private and public digital workspaces promotes collaborative knowledge building through the analysis of students' performance and interactions in a collaborative concept map. They have found that the private workspace allows students to explain their ideas in the collaborative concept map better. Researchers agree that individual preparation in the form of concept map supports the students to integrate ideas for consensus building (Fischer et al., 2002; Gracia-Moreno et al., 2017). In this study, we also utilize concept map construction both for individual preparation and collaborative task. Different from the previous studies explained before, we apply a specific approach of concept mapping activities, named Reciprocal Kit Build during the individual (preparation) phase and the collaboration phase.

2.2 Kit Build Concept Map

Kit Build (KB) is a closed-ended approach of a concept map (Hirashima, Yamasaki, Fukuda, & Funaoi, 2015). In KB approach, a teacher defines a structure and components of the map while the students then try to rebuild the map. First, a teacher creates a concept map that will become a goal map. The KB system will decompose the map into nodes and links called kit. Next, the students will be asked to reconstruct the concept map from the provided kit. The system will display a comparison between the teacher's map and the students' concept map in the KB analyzer. There are three types of links shown: correct links, excessive links, and lacking links. Correct links show that students make correct propositions as appeared in the goal map, excessive links indicate that students make propositions that are not defined by the teacher, and lacking links show teacher's propositions that are not reconstructed by students. The analyzer displays group and individual comprehension as a feedback to the teacher.

Yoshida et al. (2013) have examined the practical use of Kit Build to evaluate students' understanding of the ongoing classroom. The information provided by Kit Build supplemented the teaching and used to improve the lesson plan in the subsequent class. Some previous studies confirmed the validity of Kit Build as an assessment tool with other conventional concept map evaluation methods (Wunnasri, Pailai, Hayashi, & Hirashima, 2018c). KB map reduces loads of the teacher to evaluate students' understanding. Thus he can quickly find misconceptions and help students to correct them. The use of Kit Build in collaborative learning is potential as a tool for students to exchange ideas and to evaluate mutual understanding in the form of concept maps.

One of the extensions of the Kit Build approach is the Reciprocal Kit Build (abbreviated as RKB) (Wunnasri, Pailai, Hayashi, & Hirashima, 2018a). The main activities are the same, i.e., there is someone who created the initial concept map, and others are making a map based on the elements in the initial map concept (kit). At this stage, we expect that the person who reconstructs the partner concept map can find the structure of the initial concept map. The system will display a comparison map containing similarities and differences between the initial map and the partner's reconstructed map. The difference between the KB and the RKB lies in the interaction pattern and students' freedom to create a concept map. In the Reciprocal Kit Build interaction takes place between two people with a relatively similar level of expertise, whereas in the KB interaction occurs between a person who acts as an expert with others who have a lower level of expertise (e.g., between teacher and his students). In the RKB, the group members are free to create the initial concept map. However, it would be better to determine the nodes first to facilitate reconstruction and evaluation by the partner.

The goal of RKB in group communication is not merely for evaluation, but also to share understanding. The initial research of Reciprocal Kit Build shows that this approach leads to a more productive discussion (Wunnasri et al., 2018b, 2018a). By reconstructing a concept map from the partner's kit, students are trying to understand other person's perspectives. A discussion that occurs when the system displays a comparison map causes the subjects to perform more exploratory talk. Therefore, we hope that the RKB is suitable to be used in a collaborative learning environment. However, there is no study have explored the effects of RKB usage on collaborative tasks.

3. Method

3.1 Participants & Context of Study

The participants of this study were forty-four first-year students of Linear Algebra class at the Faculty of Computer Science at one of the large public universities in Indonesia. Each group consists of two people. They were familiar with using computer software for learning. An experienced lecturer who taught this subject was used to apply active learning and social constructivism learning theory. Students were also accustomed to join in the collaborative learning activities in both online and face-to-face session, such as online collaborative discussion, jigsaw, and think-pair-share technique.

In this study, we chose the Inner Product Space as a topic covered in the concept map. To understand this topic well, the students were required to do accommodation related to the concept of a vector. From the vector as a directed line segment or a magnitude with length and direction to vector as an element of the Vector Space. The students were expected to apply the new vector concept in the context of Inner Product Space.

This topic is fit to be discussed in the form of a concept map because students are required to create a cross-link between two lessons, e.g., the vector space and the inner product function. In this topic, the connection between the two concepts is well-defined and less variation. The primary challenge is when students have to define a correct annotation and to construct the structure between the nodes, so the map includes all the essential concepts (comprehensiveness) and hierarchically structured. Both teacher and students had ever conducted mapping activities in some previous lessons, so students were acquainted with the way to create a link between concepts.

Associated with the task given in the experiment, the teacher had provided an introductory material first, but never made or asked students to construct a concept map. Students created concept maps based on concepts given by the teacher ($n = 15$). Therefore all essential concepts were included in the students' map. The teacher integrated this experiment as one learning activity and adopted the concept map score as one of the components of students' mid-term test.

3.2 Experimental Settings

We conducted the experiments in the computer laboratory and the classroom. Students had already informed that they would create a concept map by using Kit Build application. Though they had created a concept map with paper and pencil, they have no previous experienced with Kit Build. The teacher allowed students to choose their partners and to use their laptop computers so that they feel comfortable conveying their ideas and following the activities. Students sat side by side with their partners in a group. During the experiment, the teacher permitted students to open relevant learning materials. This experiment consists of 4 phases, i.e., introduction phase, individual phase, collaboration phase, and feedback phase. The feedback phase was held in the classroom after the students created the concept map. We conducted the activities following the timeline in Table 1.

Table 1

The experiments schedule

Phase	Teacher's activity	Students' activity	Duration
Introduction	explain the task and the way to use the system	• Kit Build practice	5' 15'
Individual	act as facilitator	• create a concept map based on the given nodes (concepts)	15'
Collaboration	act as facilitator	• reconstruct the map based on the partner's kit • discuss the comparison map • create a group concept map	20' 20'
Feedback	provide feedback		30'

For an introductory phase, the teacher explained the purpose of this activity and introduced the Kit Build application. Students who have never created a concept map with the Kit Build were trying to make a simple concept map, so they were familiar with the interface. By doing so, we expected that it would reduce the technical difficulties found by students.

In the individual phase, students created an individual concept map based on the predefined nodes. This activity enabled students to externalize their prior knowledge. There are 15 concept nodes provided, including inner product space, vector space, vector, directed line segment, domain: VxV, codomain: R, inner product function, additivity axiom, homogeneity axiom, positivity axiom, symmetry axiom, orthogonal projection, distance between two vectors, length of a vector, and angle between two vectors. The teacher allowed students to make a concept map with as many nodes as possible.

In the collaboration phase, there were two main activities performed by the students. First, students tried to reconstruct a concept map based on the nodes and links (kit) provided by the partner. After that, the RKB will show the similarities and differences between the reconstructed concept map and the initial concept map created in the individual phase (a comparison map). The comparison map consists of agree links, excessive links, and lacking links. If a student rebuilds the same proposition as his/her partner, the link becomes an agree link. It belongs to an excessive link when the student creates a proposition that does not exist in the partner's map. A lacking link shows a partner's link that is not rebuilt by the student. We expected students were trying to understand their partner's comprehension.

Providing the comparison map might lead elicitation of partner understanding since students were able to detect missing information in the partner's representation. Additionally, it supported students to discover the different point of views, and stimulated task-related cognitive activity and result in progress (conflict-oriented consensus-building stage). Finally, students created a group concept map together as the final concept map (integration-oriented consensus-building stage). We illustrate these activities in Figure 1.

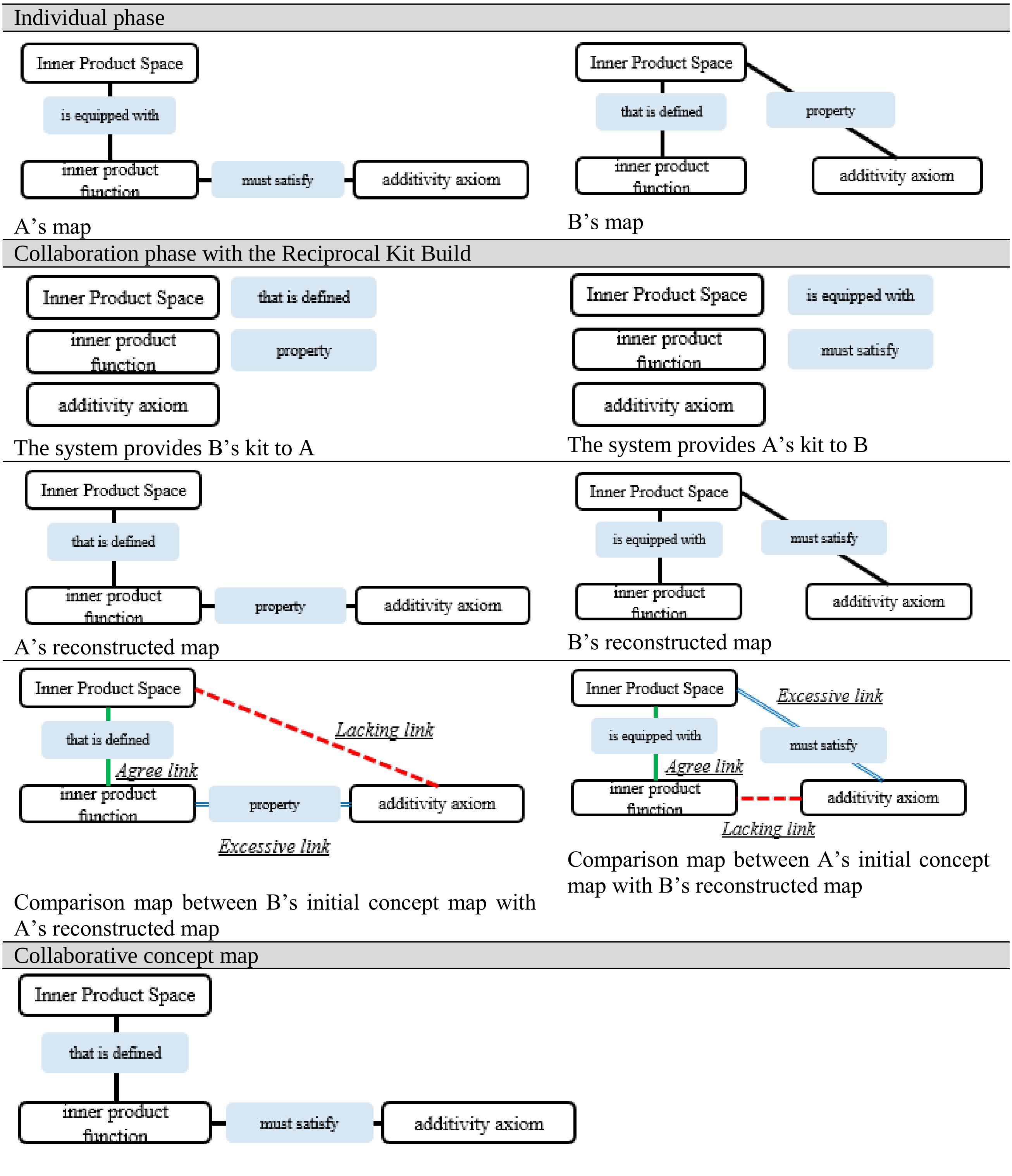

Figure 1. The flow of students' activities using the Reciprocal Kit Build before creating a group map

In the next session, the teacher provided general feedback to students based on their maps. The teacher identified true propositions and common misconceptions. The teacher also acknowledged the students who make a good concept map. This feedback phase is essential to appreciate student participation and to correct misconceptions. The scores of both individual and group maps are aggregated and were included for the individual mid-term evaluations.

3.3 Measurement

In this study, we measured students' learning performances from the concept maps created in the individual phase and collaboration phase. Before the experiment, the teacher had composed an expert map and created a grading rubric following the map. The rubric contains a schema determines the score of a proposition based on the presence of connections (links) between two concepts and the accuracy of annotation. From all 15 nodes provided to students, the teacher expected that there should be at least 14 valid propositions. The score for every proposition will belong to one of four categories including a true proposition (10 points), a false proposition with a minor, moderate, or fatal error with the weight of 8, 5, 0 points accordingly. All propositions scores were aggregated and normalized from 0 to 100 ranges. The teacher conducted the assessment independently, as in a common class setting. We identified the effect of the proposed procedure by assessing group performances, not individual performances, as suggested by Dillenbourg (1999). Measurement of group performance is more appropriate because it reflects the results of the collaboration between students as members of a group.

We also observed all comparison maps to identify changes in students' final concept map. We analyzed the propositional changes from the individual map into group map based on the links obtained from the comparison map of each group. We measured whether there is a correlation between the content displayed on the comparison map and the accuracy changes in the student propositions. We found out whether the visualization provided by the RKB system influenced the group maps.

4. Results & Discussion

We divide this section into two sub-sections based on the research questions. First, we analyzed the changes of concept map scores between the individual phase and collaboration phase to measure students' learning achievements. Next, we identified the effect of the comparison map on student proposition changes based on data obtained from the Reciprocal Kit Build system.

4.1.1 The Effect of Proposed Procedures on Students' Learning Performances

We evaluated improvements of group performances based on the concept maps generated at the individual and the collaboration phase. As the initial group score, we calculated the average value of the individual concept map within a group, while the final score obtained from the group map. The total number of the group is 22. On average the final group score is increasing (Table 2).

Table 2

Descriptive statistics of the Initial Group Score and the Final Group Score

Item	Initial Group Score	Final Group Score
Mean	**70.35**	**85.51**
Standard Deviation	18.90	10.14
Minimum	37.14	67.14
Maximum	100	100

Furthermore, we did a statistical test to see if the changes were significant. Before performing the t-test, we tested whether the variances of the two scores from the same populations are equal by using the f-test. In this case, $F = 3.4724$ and F Critical one-tail = 2.0842, which shows that variances between the two scores are unequal. Next, we did a t-test for the case of unequal variances. The data does not have outliers. The data is normally distributed based on the

Shapiro-Wilk Test ($\alpha = 0.05$, p-value: 0.126). We also did a paired-sample T-test, using T distribution (DF=21) (two-tailed). The difference between the average of the Final Group Score minus Initial Group Score and $\mu 0$ is statistically significant (p-value: 0.000559955). The observed standardized effect size is large (0.87).

Overall, the number of true propositions in all group maps is increasing (Figure 2), even though the teachers did not provide feedback on individual maps nor intervene in students' discussion. From both diagrams, we also see that the number of false propositions has decreased by 17%, from 36% to 19%. Mainly, there is a decrease in the false propositions with a fatal error as much as 16%. After creating an individual concept map, students were asked to recreate a concept map from their partner's kit and discussed the results before creating a group map together. Therefore, we estimate that the discourse during those activities was productive for students to confirm and clarify their understanding.

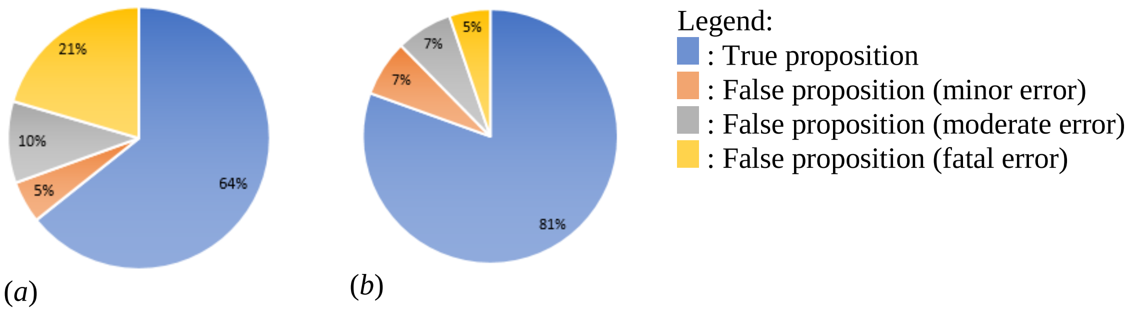

Figure 2. (*a*). Distribution of true and false propositions in all initial maps; (*b*) Distribution of true and false propositions in the final group maps

Furthermore, we also explored how far the accuracy of students' propositions from the initial maps had changed in the group maps. We tried to figure out the students' tendency to change his original proposition. Following the teacher's rubric that covers 14 propositions, we determined changes of students proposition accuracy; whether a true proposition in students' initial map becomes a false proposition in the group map, or still correct. We applied the similar treatment to the false proposition. Next, we categorized the changes into three types: positive revision, negative revision, and not change. Positive revision means that students improve the proposition quality, for example by creating a correct link between the two connected concepts or defining a correct annotation in the group map, which was not available in the individual map. We applied the opposite way to define negative revision; the students' proposition changes into a false proposition in the group map while in the individual map they had created a better one. Based on those categories, we found that 409 propositions in individual maps have the same truth value as in the group map, 163 propositions increased in their truth value, and 44 propositions decreased. We conclude that students negotiated 33% of their original propositions and 78% of modified propositions become more accurate than its initial propositions.

4.1.2 The Effect of Kit Build Visualization on Students' Performances

We have seen that students have revised some of their initial propositions in their group map, without any feedback from the teacher. It may indicate that they have reflected their knowledge and been facing cognitive conflict with their peer which lead to positive changes following our procedures. Since the RKB facilitated these processes, it is necessary to analyze further the dynamics of a pair understanding represented in the comparison map.

After creating the individual maps, students exchanged ideas using the RKB. In this phase, they reconstructed a concept map based on the links and nodes provided by the partner. The system also showed a comparison map which highlights the similarities and differences between the reconstructed map and the initial individual map. There are three types of links shown, i.e., agree link, excessive link, and lacking link. Agree link illustrated the student had reconstructed the same proposition as in the partner's map, while excessive and lacking links illustrated the different proposition made by the partner. Based on the data obtained, there are 468 agree links, 139 excessive links, and 142 lacking links. The number of lacking links is more than the excessive links because the student may not connect the relation (links) to any concept.

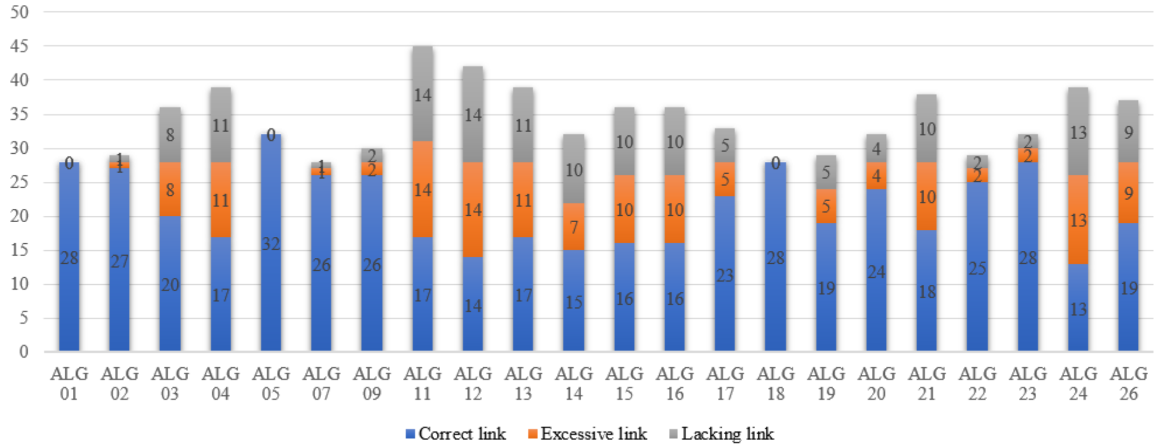

Figure 3. Distribution of the links similarities and differences constructed by all groups

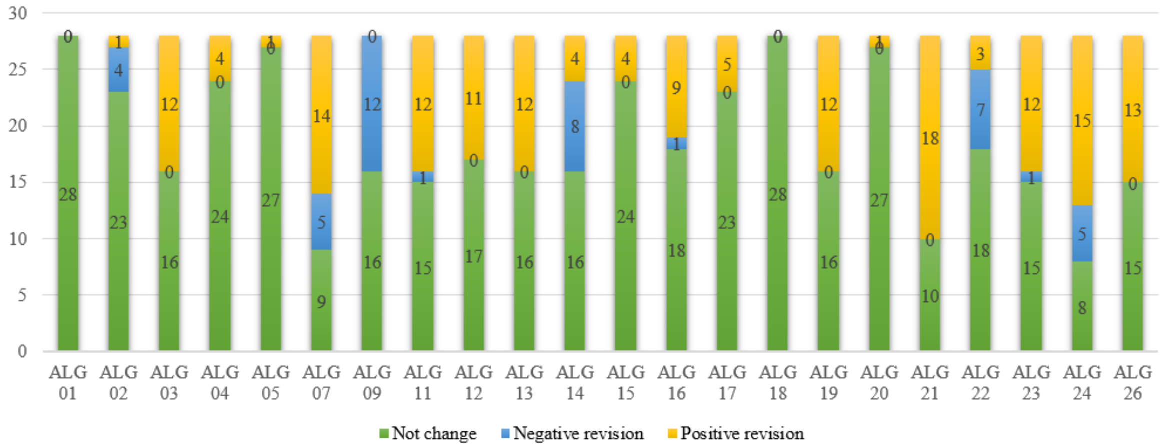

Figure 4. Distribution of changes in the propositions quality (truth level) for all groups

Based on Figure 3 and Figure 4, we predicted that, in specific groups, the number of excessive links and lacking links also influences the proposition accuracy changes made in the group map. Therefore, we calculate the correlation between those two. In this analysis, we selected only excessive links, without the lacking links because the number of excessive links and lacking links is relatively similar and primarily it represented the same information, that is a different opinion about a particular proposition between a dyad.

Table 3

Correlation between the type of proposition quality change and excessive links

Type of proposition quality change	Excessive link	Agree link
Revision	**0.418** (*p-value*: 0.05235)	
Positive revision	**0.583** (*p-value*: 0.00435)	
Negative revision	-0.250 (*p-value*: 0.26058)	
Not change		**0.464** (*p-value*: 0.0295)

In general, the change in proposition quality has a moderate positive correlation with the number of excessive links. For the positive revision, when the groups have more excessive links, they are more likely to create a better proposition in the group map, and the correlation coefficient is significantly different from zero. It seems that when a student has a different opinion within the group, he/she tries to correct own understanding. There is a weak negative correlation between the number of excessive links and the decreasing accuracy of propositions in the group map. There are only 44 out of 616 propositions changed into less accurate propositions. It needs to be further analyzed why it is occurred, especially in ALG 09 group. Table 3 also shows that there is a moderate positive correlation between the number of propositions that do not change with the number of the same proposition made by a student from the partner's kit. It means there is a chance that a partner with a high level of agreement tends not to change his understanding, for example in the ALG 01 and ALG 18 group.

Now, we focus on the excessive links since it represents the different point of views within a group. We explored how many proposition changes in the group map following the visualization of excessive links. Figure 5 shows the distribution of these changes based on the excessive links only. There are 19 out of 22 groups who have excessive links. From the 139 excessive links shown to the students, 78% of propositions change to true propositions. Twenty of the 44 false propositions have a minor error.

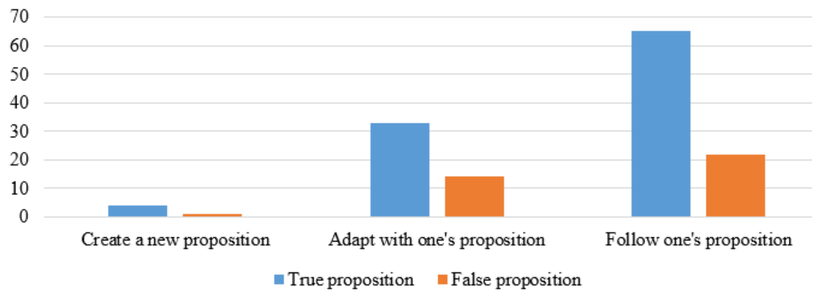

Figure 5. The distribution of changes in group propositions from all excessive links (n = 139)

We also investigated how students' tendency when partners make different propositions to their original propositions (excessive links). Based on these excessive links, we have explored how the group determined the propositions used in the group map. Did they follow the full proposition of one member of the group, adapt existing, or compose a new proposition? Based on the similarity between the connectedness of two nodes and the link definition, we divided three trends of the group propositions:

- Follow one's proposition: propositions created in the group map follow one member completely, both regarding the link between the two concepts and the annotation between these concepts. A total of 41 of 65 propositions follow one of the true propositions. The visualization helps students to realize own mistakes, then they discover information from their partner and tend to decide the true proposition.
- Adapt with a partner's proposition: propositions written in the group map accommodate the proposition of one member but do not change completely. It is possible for students to define a different link (relationship) they have made in the individual phase, while still using the link between the old nodes. A total of 33 of 47 propositions adapted to the proposition created by the other member in the individual phase and formed a true proposition. It shows that a proposition created by the group member is partially correct and should to be adjusted so others would not have a different understanding.
- Create a new proposition: the propositions in the group map are new and not available in the propositions appeared at the individual phase (n = 5). Four of the five propositions are true. It shows that when students do not make propositions according to partner expectations, there is a possibility that both of them are exploring information from other learning sources and realizing their understanding was wrong.

A total of 134 of 139 total excessive links of students were adopted from the individual proposition to be a group proposition. In general, students tend to consider the opinions of their partner when they have a cognitive conflict visualized by the excessive links.

5. Conclusion and Future Works

Following the proposed procedures, there is a significant improvement in students' learning achievement regarding the accuracy of group map even though the teacher kept minimum intervention during the discourse. The false proposition reduced from 35% to 19%. It may indicate that the overall group has a productive discussion facilitated by the Kit Build application. The visualization of the difference map, especially excessive links, has a moderate positive correlation with the positive changes in the group propositions. The visualization may help students to see the different views of partner's understanding and to reach a better consensus. The RKB approach also potential to give personalized feedback from the learning partner after they had reconstructed map from the partner's kit.

This preliminary study explores the use of Reciprocal Kit Build for creating a collaborative concept map. In this study, the RKB approach was used for Linear Algebra subject in which have a clear correct and incorrect link among concepts, but no so far more complex topics. The effect of the treatment only measures from a single group. The more comprehensive analysis should be done at every stage of the collaborative learning process (externalization, elicitation, and consensus building). Further, students' cognitive load in one experiment session are rather high since they have to construct a map from scratch, for at least three times. For the future work, it may be better to differentiate the individual phase and collaboration phase session. The system should provide a feature to help the teacher analyze students' maps.

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