Doctoral Thesis

Collaboration with Reciprocal Kit-Build Concept Map: An Analysis of Group Products

(相互キットビルドコンセプトマップを用いたコラボレーション：グループ生産物の分析)

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Abstract

Effective collaboration is supported by meaningful interaction between group members. Various strategies have been applied to assist learners in collaborating and creating a continuous effort to construct and maintain shared knowledge, such as utilizing a concept map as a representational tool during discourse. While prior studies have established its positive significance on the learning achievements and attitudes of students, they have also discovered that it can lead to students conducting less discussion on conceptual knowledge, compared to procedural and team coordination.

One strategy for improving the quality of students' explanations during collaborative concept mapping (CCM) is to enable them to externalize their thinking privately, beforehand. Though some studies have suggested the inclusion of an individual preparation phase before CCM, only a few studies have provided a means of sharing individual knowledge. Increased awareness of a partner's understanding is also essential in reducing miscommunication and improving the efficiency of the shared knowledge construction process. However, students also face difficulties in sharing developed ideas (private knowledge) and integrating them into public knowledge.

While previous studies proposed that the Reciprocal Kit Build (RKB) approach allows students to externalize their thinking and comprehend the representation of others' knowledge, prior to collaboration, they have yet to evaluate the approaches to building group knowledge. Therefore, this study aims to evaluate the effectiveness of the RKB approach for collaboration. To achieve this, it focuses on conducting an evaluation of the group products, students' perspectives toward the activities, and the process of transfer from individual-to-group knowledge. Further analysis of the group products and the transfer of knowledge, based on the similarity of knowledge between the group members and comprehension of their partner's representations, is performed to uncover patterns of student behavior throughout the activities. In doing so, we are able to identify factors that potentially influence the learning process.

This study was completed in a practical classroom setting at a public university in Indonesia. A linear algebra class was selected as the study subject, as the class relies on various collaborative learning approaches for both in-class and online activities. A single group design was applied to explore the effectiveness of the RKB in a natural setting.

This thesis consists of seven chapters.

- **Chapter 1** describes the research backgrounds, review of existing literature, and identifies some of the challenges to this study. The research objectives and research questions that guided the study are also presented, followed by the general structure of the thesis.

- **Chapter 2** explains some of the relevant prior research in the context of CCM, the KB concept map, and the RKB approach.

- **Chapter 3** outlines the CCM activity with RKB, the characteristics of the participants and course subject, experimental procedures, and collected data.

- **Chapter 4** presents an evaluation of group outcomes after students followed the RKB approach. It also analyzes how students change their propositions, from the individual to the collaborative phase, based on the visualization of the difference map provided by the RKB system. Perceptions of students during these activities are examined to measure the effectiveness of the approach from the viewpoints of the participants.

- **Chapter 5** aims to identify the effect of different group compositions on learning effectiveness, at the level of interaction between the individual and the group and at the level of the group as a whole.

- **Chapter 6** presents an investigation into predicting group outcomes based on individual maps: The correlations between the similarity of individual knowledge represented in the first-phase maps, the comprehension of partners' representations during the second phase, and the change of map scores are all analyzed. It also discusses the ways in which patterns of knowledge transfer from individuals to group maps, exhibiting how group products are built based on individual inputs.

- Finally, in **Chapter 7**, the study draws its conclusions and suggestions for potential future studies are made.

Based on the group products, patterns of knowledge transfer from individual-to-group, and questionnaire results, it is realized that the RKB is a promising tool in achieving high-quality, group solutions, encouraging equal participation, and obtaining acceptance from learners towards activities. The findings of this study convey that the RKB also proves promising in supporting knowledge-building in a collaborative context, despite some limitations in the practical classroom experimental settings. A thorough analysis has been conducted on multi-perspectives. An evaluation of students' acceptance towards activities and an analysis of different group formations are also essential for teachers and practitioners who intend to apply the RKB in their classrooms.

Dedication

To my family, thank you for always supporting me

Acknowledgements

Finally, if you're wondering if it counts and it feels like it counts, it counts.

— Mary H.K. Choi, Emergency Contact

Alhamdulillah. All praise belongs to Allah(swt), who showers me with His love and blessings.

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List of publications

Publications

Journal Articles

- RPTEL 2020a: **Sadita, L.**, Hirashima, T., Hayashi, Y., Furtado, P. G., Junus, K., and Santoso, H. B. (2020). The Effect of Differences in Group Composition on Knowledge Transfer, Group Achievement and Learners' Affective Responses During Reciprocal Concept Mapping With The Kit-Build Approach. *Research and Practice in Technology Enhanced Learning*, 15(13). DOI: 10.1186/s41039-020-00133-9
- IEICE 2020: **Sadita, L.**, Furtado, P. G. F., Hirashima, T., and Hayashi, Y. (2020). Analysis of The Similarity of Individual Knowledge and The Comprehension of Partner's Representation during Collaborative Concept Mapping with Reciprocal Kit Build Approach. *IEICE TRANSACTIONS on Information and Systems*, E103-D(7).
- RPTEL 2020b: **Sadita, L.**, Hirashima, T., Hayashi, Y., Wunnasri, W., Pailai, J., Junus, K., and Santoso, H. B. (2020, in press). Collaborative concept mapping with Reciprocal Kit-Build: A practical use in Linear Algebra course. *Research and Practice in Technology Enhanced Learning.*

International Conference Papers

- ICCE 2018: **Sadita, L.**, Hirashima, T., Hayashi, Y., Wunnasri, W., Pailai, J., Junus, K., and Santoso, H. B. (2018). Preliminary Study on the Use of Reciprocal Kit Build for Collaborative Learning. In *The 26th International Conference on Computers in Education (ICCE 2018)*, pages 133–142.
- ICCE 2019a: **Sadita, L.**, Hirashima, T., Hayashi, Y., Furtado, P. G., Junus, K., and Santoso, H. B. (2019). Reciprocal Kit Build Approach for Peer-to-peer Communication: Relationship between Similarities on Knowledge, Transfer of Knowledge, and Affective Responses. In *The 27th International Conference on Computers in Education (ICCE 2019)*, volume 1, pages 101–110.
- ICCE 2019b: **Sadita, L.**, Hirashima, T., and Hayashi, Y. (2019). Reciprocal Kit Build Concept Map: An Activity Designed to Encourage Learning at Boundary in Collaborative Situation. In *The 27th International Conference on Computers in Education (ICCE 2019)*, volume 2, pages 779–782.

Local Conference Paper

- ALST 2019: **Sadita, L.**, Hirashima, T., Hayashi, Y., et al. (2019). Reciprocal Kit Build:Boundary Crossing with Concept Map for Collaborative Knowledge Construction. 先進的学習科学と工学研究会, 86:50–55.

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.

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Glossary

concept map A graphical tool for organizing and representing knowledge, consisting of concepts and their relationships to facilitate meaningful learning.. 2

excessive link An excessive link indicates that students create a new proposition not previously defined by the teacher.. 9

KB A re-constructional closed-ended approach to a concept mapping activity, in which students construct a map based on predefined nodes and links extracted from an expert's map . 9

lacking link A lacking link illustrates a teacher's proposition that is not reconstructed by the students.. 9

matching link A matching link represents identical propositions in both the students' and the expert's maps. . 9

Acronyms

Chapter 1

Introduction

Summary

This chapter describes the research background, review of existing literature, and challenges to this study. The research objectives and research questions that guided the study are also presented, followed by the general structure of the thesis.

The main goal of this thesis is to evaluate the effectiveness of the RKB approach for collaboration, in terms of the group products, students' perspectives towards the activities, and the process of transfer from individual-to-group knowledge. Further analysis is performed on the group products and the transfer of knowledge (based on the similarity of knowledge between the group members and their comprehension of their partner's representation) to uncover patterns in student behavior throughout the activities. Through this analysis, we are able to identify factors that may potentially influence the learning process.

1.1 Backgrounds

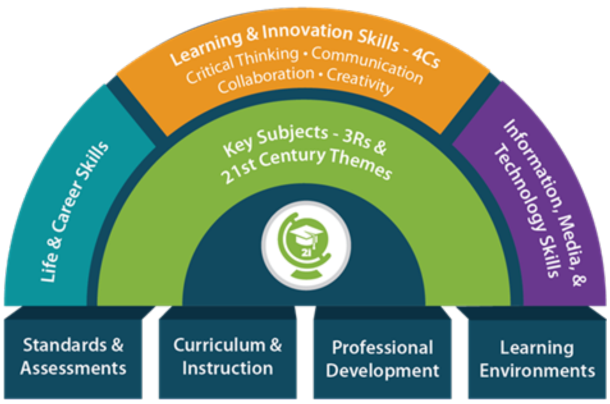

Figure 1.1: Partnership for 21st century learning. Source: `https://www.battelleforkids.org/networks/p21`

Collaboration is one of four, essential 21st century skills, along with critical thinking, communication, and creativity (see Figure 1.1). The advancement of technology and its rapidly changing environment require collaborative works from people in multidisciplinary subjects to solve complex problems effectively. Collaboration is, indeed, a necessary teaching requirement in the classroom setting, as it does not simply happen because individuals are co-present (Baines, Rubie-Davies, & Blatchford, 2009; Roschelle & Teasley, 1995; Webb, 2009). Practicing collaboration and teamwork will help students to understand how to solve problems, resolve conflicts, integrate different perspectives, and decide on the best course of action.

Teachers and researchers have explored various collaborative learning activities in their classrooms. Collaborative learning is defined as a situation in which two or more people attempt to learn something together (Dillenbourg, 1999). In line with the Social Constructivist Theory of Vygotsky and Cole (1978), some previous studies have attached great importance to students' interactions as a fundamental role in collaborative learning (Baines et al., 2009; Webb, 2009). Various instructional strategies are employed to encourage learners to collaborate, such as scripts, scenarios, and representational tools. During collaboration, individual learners need to make a continuous effort to construct and maintain group-shared knowledge (Roschelle & Teasley, 1995). However, they may forget prior discussion or experience difficulty remembering what they have previously discussed or co-constructed (Jeong & Hmelo-Silver, 2016); an external representation tool, such as a concept map, assists the learner in articulating and maintaining a shared focus during discourse (F. Fischer, Bruhn, Gräsel, & Mandl, 2002; Suthers, 2006; van Boxtel, van der Linden, Roelofs, & Erkens, 2002).

A concept map is mainly utilized as a representational tool in a collaborative setting to facilitate group discussion, as well as to communicate complex ideas (F. Fischer et al., 2002; Gracia-Moreno, Cerisier, Devauchelle, Gamboa, & Pierrot, 2017; Suthers, 2006; van Boxtel, van der Linden, & Kanselaar, 2000). It is a graphical tool for organizing and representing knowledge, consisting of concepts and the relationships among these concepts, to facilitate meaningful learning (Novak & Gowin, 1984). In a concept map, the nodes represent concepts, while the links, with their descriptive labels, explain the relationships among the concepts. Co-construction of a concept map is an effort to co-create a representational tool of group understanding—it allows learners to be consistent and achieve convergence, rather than simply through dialogue (Jeong & Hmelo-Silver, 2016; Roschelle & Teasley, 1995).

Previous studies posit that CCM has a positive effect on both the attitudes and learning achievements of students (Basque & Lavoie, 2006; Czerniak & Haney, 1998). However, conflicting evidence has also been found, indicating that students spend a considerable amount of time focusing on task collaboration, procedure, and team coordination, rather than discussions about the concepts or relationships involved (Chiu, 2003). Others have also found that students encountered difficulties in sharing developed ideas and integrating them into public knowledge (Gracia-Moreno et al., 2017; van Boxtel et al., 2000); hence, some inaccurate ideas are never challenged and can become ingrained (Roth & Roychoudhury, 1992).

It is, therefore, crucial to design learning activities during CCM that encourage more productive discussion, as well as promote the sharing of ideas. It is for this purpose that the RKB is utilized, prior to CCM. RKB is an extended version of the KB concept mapping activity to support pair discussion (Wunnasri, Pailai, Hayashi, & Hirashima, 2018a, 2018b). The KB approach enables teachers to confirm their students' understanding of the information delivered. Moreover, reconstruction activities provide a means to externalize one's understanding of the perspective of others. A reconstruction activity triggers students to communicate empathic understanding (i.e., the ability to sense what another individual is thinking or feeling) (Barak, Engle, Katzir, & Fisher, 1987) and discuss conflicting ideas.

1.2 Challenges

Initial studies showed that the RKB approach promoted productive discussion between partners, compared to the group without reconstruction and difference map-supported discussion (Wunnasri et al., 2018a). The RKB map also encouraged partners to understand each other based on the similarity score of each individual's map, after discussion (Wunnasri et al., 2018b). Their findings demonstrated that the RKB can be used to share understanding as preparation for collaboration. However, so far, they have not evaluated the effect of applying this approach to collaborative knowledge building. The following issues have not been addressed in the previous studies and research literature:

1. Collaborative product evaluation:
   After following the RKB activities, the question as to whether high-quality group products could be achieved remains. Although previous studies on CCM (F. Fischer & Mandl, 2002; Gracia-Moreno et al., 2017; Suthers, 2006; van Boxtel et al., 2000) have showed that it can help students to achieve a better solution to the problem at hand, the same result has yet to be confirmed for the RKB approach.

2. Exploring students' perceptions toward the activity:
   Applying a new learning activity as a part of practical classroom instructions, need to consider the perspective of students. Students' engagement throughout the activities would influence the learning process. An evaluation regarding students' acceptance is as important as the learning product itself.

3. Analyzing the effect of different group formation on collaboration:
   A central question of research and practice in collaborative learning is how learners within a group influence each other and manage to converge their knowledge (F. Fischer & Mandl, 2002; Weinberger, Stegmann, & Fischer, 2007). Research suggests that, when forming a group, we need to consider the similarity of individual knowledge, as preconceptions and divergence in knowledge influence the benefits experienced by group members in collaborative learning (Weinberger & Fischer, 2006). Therefore, an investigation into how individual differences in knowledge may influence collaborative learning effectiveness is necessary to reveal the role of RKB in collaboration, as well as to determine the appropriate group setting.

4. Predicting group outcomes based on individual maps:
   Identifying the relationship between the individual and the group products is essential, as there is interdependence between these two. However, it raises the issues of how to foresee students' learning achievements as a group, based on the maps created during the individual phases (i.e., the initial and re-constructional maps), and whether the similarity of the first maps, or comprehension of a partner's representation depicted in the second maps, could be used to predict group outcomes. It also raises the question of how an individual's knowledge is employed to constructively build the group's solution. Findings from this investigation are useful in designing supporting functions for CCM.

1.3 Research objectives

Based on the challenges mentioned above, the main purposes of this study are defined as follows:

1. To identify the effectiveness of the RKB approach for CCM in a practical classroom based on the group products, students' perceptions towards the activities, and the patterns of map changes from individuals to groups.

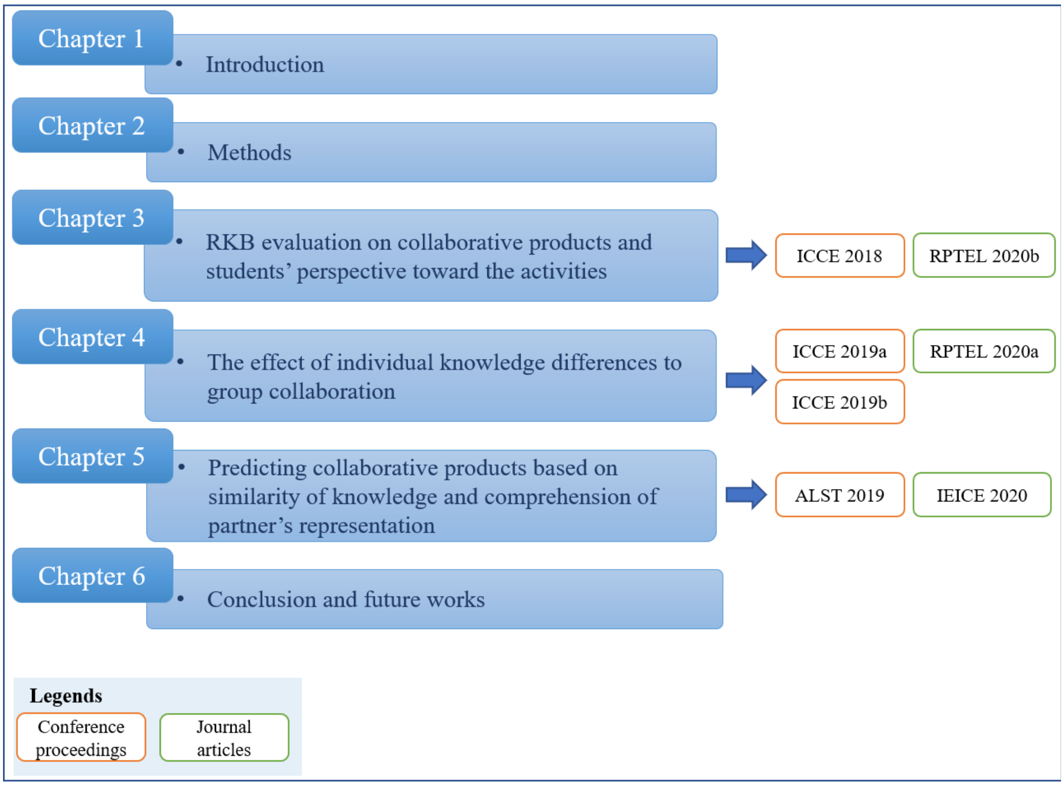

Figure 1.2: Structure of the thesis and related publications

2. To investigate how individual differences in prior knowledge potentially influences collaborative-learning effectiveness and the students' perceptions towards the activities.

3. To analyze how similarity of individual knowledge and comprehension of a partner's representation could predict the final collaborative products.

These initial research objectives could provide a comprehensive understanding of the effectiveness of the RKB approach for collaboration and valuable insights for practitioners who want to apply the RKB in their classroom.

1.4 Thesis structure

This section describes the chapters of the thesis; the structure of the thesis and the publications associated with each chapter are illustrated in Figure 1.2.

- **Chapter 1: Introduction**
  This chapter describes the research background, motivation, review of existing literature, and problem statements. The research objectives and research questions that guide the study are also presented, followed by the general structure of the thesis.

- **Chapter 2: Related works**
  This chapter explains relevant prior research in the context of CCM, the KB concept map, and the RKB approach.

- **Chapter 3: Methods**
  This chapter outlines the CCM activity with RKB, the characteristics of the participants and course subject, experimental procedures, and the collected data.

- **Chapter 4: RKB evaluation on collaborative products and students' perspectives towards the activities**
  This chapter focuses on the first research aim: To identify the effectiveness of the RKB approach for CCM in a practical classroom (Sadita et al., 2018; Sadita, Hirashima, Hayashi, Wunnasri, et al., 2020). The effect on the group of utilizing the RKB as learning activities is evaluated. How students change their propositions, from the individual to the collaborative phase, following the visualization of the difference map provided by the RKB system, is also presented. Students' perceptions during these activities are examined to measure the effectiveness of the approach from the viewpoint of the participants.

- **Chapter 5: The effect of individual knowledge differences to group collaboration**
  This chapter presents the analysis of the second research objective: To investigate how individual differences in prior knowledge potentially influences collaborative learning effectiveness and students' perceptions towards the activities (Sadita, Hirashima, & Hayashi, 2019; Sadita, Hirashima, Hayashi, Furtado, et al., 2019, 2020). The effect of different group formation on learning effectiveness is measured at two levels-—interaction between the individual and the group, and at the level of the group as a whole. The transfer of an individual's shared and unshared knowledge to group products, in all group conditions, is evaluated. How group formation may prompt learners to experience different perspectives toward the activities.

- **Chapter 6: Predicting collaborative products based on the similarity of knowledge and comprehension of a partner's representation**
  This chapter presents the evaluation of the third research objective: To analyze how the similarity of individual knowledge and comprehension of a partner's representation could predict the final collaborative products (Sadita, Furtado, Hirashima, & Hayashi, 2020; Sadita, Hirashima, Hayashi, et al., 2019). We analyze the correlations between the similarity of individual knowledge represented in the first-phase maps, the comprehension of a partner's representation during the second phase, and the changes in map scores. It also discusses the ways in which patterns of knowledge transfer from individual to group maps, which exhibit how the group products are built based on individual inputs.

- **Chapter 7: Conclusion and future works**
  This chapter revisits the studies presented in this thesis makes suggestions for possible future studies.

Chapter 2

Related works

Summary

This chapter explains relevant prior research in the context of CCM, the KB concept map, and the RKB approach. One strategy for improving the quality of students' explanations during CCM is to enable them to externalize their thinking privately and increase the awareness of a partner's understanding, beforehand. Related research in the KB concept map shows how this activity is useful to confirm students' understanding as well as determine further intervention in the classroom. However, only a few research concerns on how to apply the approach in the context of collaborative learning. While those initial studies proposed that the RKB approach allows students to externalize their thinking and comprehend the representation of others' knowledge, they have yet to evaluate the approaches to building group knowledge.

2.1 Collaborative concept mapping

Since individual knowledge structures (i.e. schemata or mental models) are not directly observable, an externalized representational tool is required to explain the complex phenomena of human learning, reasoning and problem-solving (Hirashima & Hayashi, 2016; Ifenthaler, 2010). Manipulation of such external representation may promote sophistication of internal representation (learning). Hay, Kinchin and Baker describe four important uses of concept mapping in higher education: to identify students' prior knowledge, to facilitate meaningful learning, to share knowledge and understanding between teachers and learners and to detect learners' conceptual changes (Hay, Kinchin, & Lygo-Baker, 2008). In this study, we use a concept map as an external-representation tool of students' mental models (schemata). A concept map is a graphical structure that illustrates one's cognitive knowledge, consisting of concepts and the relationships between concepts (links)(Novak & Gowin, 1984).

F. Fischer et al. (2002) divided 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. Using a concept map as a visualization tool in collaborative learning has the potential to support all these processes. The externalization of abstract concepts and the relationship between them can serve as a common ground to ensure that interaction partners understand each other (Jeong & Hmelo-Silver, 2016; Roschelle & Teasley, 1995). This representation may trigger a question and lead to elicitation of knowledge (F. Fischer et al., 2002) because students' thinking turns into explicit for sharing and misinterpretation can be clarified (Beers, Boshuizen, Kirschner, & Gijselaers, 2006; Correia, Infante-Malachias, & Godoy, 2008). The concept map also reduces the ambiguity of utterances and different views is easily recognizable resulting in cognitive conflicts and negotiation of meaning to reach a consensus (Chiu, Huang, & Chang, 2000; F. Fischer et al., 2002; Gao, Thomson, & Shen, 2013; Jeong & Hmelo-Silver, 2016; Stahl, Koschmann, & Suthers, 2006; Wang, Cheng, Chen, Mercer, & Kirschner, 2017).

Some previous researches have examined the effect of collaborative concept mapping on attitudes. Their findings postulated that collaborative concept mapping can facilitate group motivational-emotional experiences and reduced participants' anxieties (Czerniak & Haney, 1998), increasing group motivations (Beers et al., 2006). Students took more responsibility for learning (van Boxtel et al., 2002), while the quantity of group interaction is significantly correlated to the group concept mapping performance (Chiu, Huang, & Chang, 2000). In summary, studies posited that concept mapping has a positive effect on both students' attitudes and learning achievements (Basque & Lavoie, 2006; Czerniak & Haney, 1998).

Before creating a concept map collaboratively, previous studies suggested an individual preparation phase by creating a design of the concept map in the learners' own private spaces (de Weerd, Tan, & Stoyanov, 2017; Gracia-Moreno et al., 2017; van Boxtel et al., 2000). By designing an initial map individually, students had time to reflect, organize, and develop their understanding which leads to better explanation during the discussion (Gao, 2007; Gracia-Moreno et al., 2017; van Boxtel et al., 2000). They also asked more questions and demonstrated more openness exhibited to group contributions because they were allowed to elicit information that is relevant to their ambiguity from their partner (de Weerd et al., 2017; Gao, 2007; van Boxtel et al., 2002). Furthermore, the groups with individual preparation outperformed the group without preparation in their post-tests (van Boxtel et al., 2000).

However, conflicting evidences have also been found. Students in the individual preparation group encountered difficulties in sharing developed ideas and integrating them into public knowledge in the group map (Gracia-Moreno et al., 2017; van Boxtel et al., 2000). As a result, some inaccurate ideas are never challenged and can become ingrained (Roth & Roychoudhury, 1992). When students worked in a personal workspace, they preferred refusing others' ideas by deleting them directly in the digital space instead of opposing them through talk (Gracia-Moreno et al., 2017). Others have also indicated that students spend a considerable amount of time focusing on task collaboration, procedure and team coordination, rather than on discussions about the concepts or relationships involved (Chiu, 2003).

Furthermore, the externalization of students' thinking is an important requirement to find misrepresentation. When students' knowledge is visible, they can exchange their own understanding and track similarities and differences between each other's representation. At this stage, students may face socio-cognitive conflicts that are considered necessary for conceptual changes in collaborative learning (Limón, 2001; Nastasi & Clements., 1992). Socio-cognitive conflict is defined as an interaction, active engagement of participants in a cognitive controversy or confrontation leading to points of view, interpretations, different solutions, which makes group members overcome the differences together and come up with joint solutions (Iancu, 2014). Based on those recommendations, the current study highlights that concept map sharing and negotiation activities have the potential to foster conceptual changes. Active inquiry to resolve conflicts is one of the critical roles in knowledge construction, which can increase the number of shared-knowledge that all group members had after collaboration (Beers et al., 2006; Chan, Burtis, & Bereiter, 1997; Chen, Allen, & Jonassen, 2018; Kalishman, Stoddard, & O'Sullivan, 2012; Roschelle, 1992; Roschelle & Teasley, 1995; van Boxtel et al., 2000).

When students' prior knowledge is shared, they can be aware of the partners' un-

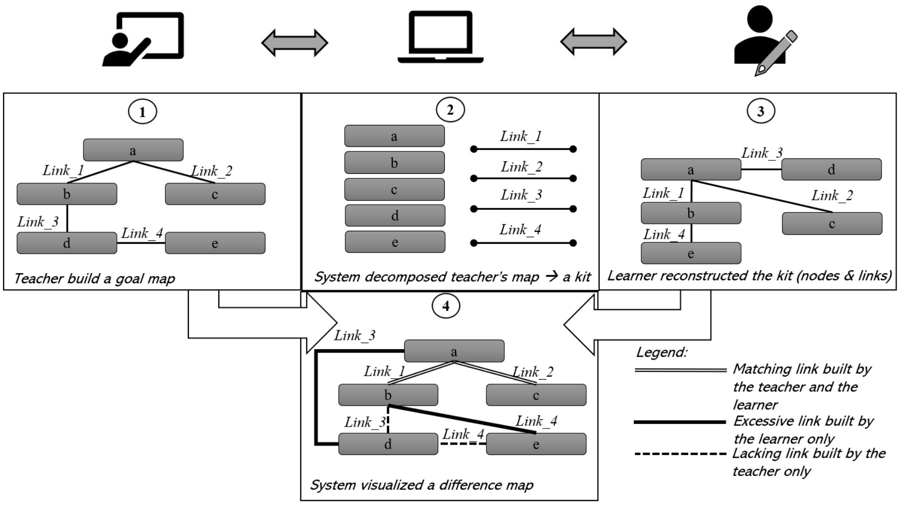

Figure 2.1: Overview of the KB approach

derstanding, which is essential to reduce miscommunication (Nickerson, 1999). When knowledge of a partner's information is lacking, a self-heuristic is applied to estimate the knowledge of others i.e., using one's knowledge. Imputing one's knowledge to others may result in overestimation, a situation when speakers expected the audience to know everything they know (Nickerson, 1999). Sharing the partner's concept map and the access to a resource underlying this knowledge improved the efficiency of knowledge co-construction because students did not need to collect information and able to directly start the problem-solving process (Engelmann & Hesse, 2010). Rather than showing the initial map to the partners' we propose an approach to exchange individual ideas through concept map re-construction. By doing so, the students would potentially exchange their ideas as well as compare each other's representation supported by the KB analyzer.

2.2 Kit-Build (KB) concept map

The current study has extended collaborative concept mapping with the KB method, a re-constructional closed-ended approach to concept mapping activity in which students construct a map based on predefined nodes and links extracted from an expert's map (Hirashima, 2019; Hirashima, Yamasaki, Fukuda, & Funaoi, 2015). Figure 2.1 illustrates the activity between a teacher and his/her students during KB concept mapping in a conventional classroom. First, the teacher develop an expert's map based on the learning materials given prior to the activity (step 1). Next, the KB system will decompose the expert's map into unconnected pieces of nodes and links. The system will then show those components to be reconstructed by the learners (step 2). During map re-construction, the learners need to find the concept map structure (step 3). After all students complete their maps, the KB system performs a similarity matching and presents it results to the teacher. Given the same map components, the similarity matching between the expert's and students' maps is feasible to complete in a timely manner. The KB analyzer displays three types of links: matching link. excessive link, and lacking link (step 4). A matching link represents that the student creates the same proposition as appeared in the expert map, an excessive link link indicates that students create a new proposition that has not been defined by the teacher, while a lacking link illustrates a teacher's proposition that is not reconstructed by the students.

The KB approach enables the teacher to confirm students' understanding of the in-

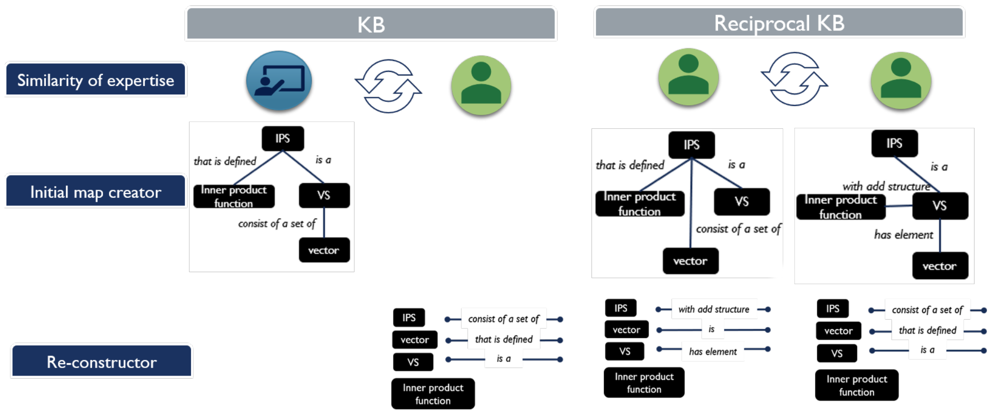

Figure 2.2: Differences between KB and RKB

formation delivered by him/her that could provide insights for the teacher to determine further intervention. In classroom practice, the KB analyzer has been used to find learners' misconceptions and to improve the teacher's lesson plan for the subsequent class (Hayashi, Murotsu, Yamamoto, & Hirashima, 2017; Hirashima et al., 2015; Kitamura, Yamanaka, Maeda, Hayashi, & Hirashima, 2016; Pailai, Wunnasri, Yoshida, Hayashi, & Hirashima, 2017; Yoshida et al., 2013). KB automatic assessment achieved almost the same level of validity as well-known concept map manual assessment methods (Wunnasri, Pailai, Hayashi, & Hirashima, 2016). From the perspectives of students, it may help them to reflect on their learning progress, which is essential to develop their knowledge structures. The KB approach is a means to exchange ideas between two different community of practices at boundaries, so they can identify the intersecting practices or reflect on dissimilar perspectives. While many studies are concerned with the effect of the KB method on individual learning (Alkhateeb, Hayashi, Rajab, & Hirashima, 2016; Hirashima et al., 2015; Kitamura et al., 2016; Pailai, Wunnasri, Hayashi, & Hirashima, 2016; Yoshida et al., 2013), only a few studies have evaluated its effectiveness in a collaborative context.

2.3 Collaborative concept mapping with RKB approach

Standard KB practice involves interaction between a teacher and their students, who have different levels of expertise regarding the subject field. Unlike the standard KB, a dyad in the RKB has a similar level of expertise (novice-novice). Each group member is also allowed to define the initial knowledge structure (map) and reconstruct the partner's map.

Learning activities during the RKB session consists of three main parts, such as individual map building, individual map reconstruction by partners, and difference map discussion (Wunnasri et al., 2018a). The initial map components are decomposed to be reconstructed by the collaborating partner. Subsequently, the system performed a propositional-level exact matching to identify the similarities and differences between the initial map and the KB map. The system compared the connecting line (links) as well as the linking words that defined the relationship between two nodes. Afterward, each group conducted a discussion guided by difference map visualization, consisting of matching links, excessive links, and lacking links. The matching link represents that the partner connected the same link and linking words as in the initial map. While the excessive link denotes a new connection that only appeared in the partner's map and the lacking link signifies initial linking words that could not be reconstructed by the partner. This approach allows students to externalize their thinking in a private space, elicits knowledge of partners, and resolves conflict through visualization of a difference map. By doing so, students had the opportunity to reflect their thinking on their maps as well as their partners' maps.

Encouraging empathic communication and collaboration with KB approach

Concept mapping activity with RKB approach allow ones to externalize their understanding of the perspective of others. Listening to others and understanding others' points of view are key functions to collaborate effectively. Effective collaboration is fueled by empathy - *an awareness of others and an ability to detect their emotions and understand their perspective*. To come up with truly innovative solutions requires new ideas and to bring new ideas requires seeking a diversity of perspectives and creating a welcoming space for people to share their ideas without fear of judgment. Therefore, the RKB activity could potentially assist students to nurture their critical thinking, encourage emphatic communication and collaboration, and trigger creativity to build new ideas.

Initial studies conducted by Wunnasri et al. in 2018 (Wunnasri et al., 2018a, 2018b) find that the KB approach promoted more exploratory talk during group discussion and assisted group members to develop a similar understanding, based on their individual first and post hoc maps. Those studies do not, however, take into account how individual knowledge is elaborated while constructing a collaborative map as an artifact that represents group consensus and shared understanding.

Chapter 3

Experimental settings

Summary

This chapter outlines the CCM activity with RKB, the characteristics of participants and course subject, experimental procedures, and collected data. The study is implemented in a practical classroom setting at a public university in Indonesia. A linear algebra class was selected as the study subject, as the class implements various collaborative learning approaches for both in-class and online activities. A single group design was applied to explore the effectiveness in a natural setting.

3.1 Proposed activity: Reciprocal Kit-Build

In this study, we apply the RKB as a designated activity before collaborative concept mapping. The learning activity is divided into two different phases, i.e. individual and collaborative phases, as follows:

a Individual phase

  a Initial map construction.
  Given a set of common nodes, students are requested to build a concept map represented their individual understanding of a topic. The expert selects essential concepts to be included in the students' maps. These nodes will serve as a boundary object for students to externalize their ideas, as well as to organize their discussion in the further step.

  b Reconstructional map building.
  After students externalize their understanding, the KB system will then decompose students' initial map into unconnected nodes and linking words. Those components will be a kit for their partner in reconstructing the initial map. The students need to actively manipulate the components (boundary objects) to find out how their partner thinks about the solution.

b Collaborative phase

  a Group discussion facilitated by the KB differences map.
  There are two reconstructed maps involving the same components which may have different structures. The system will then able to do similarity matching between propositions in the initial maps and the reconstructed maps. There are three types of propositions displayed i.e. matching links, excessive links, and lacking links. The matching links represent a similar proposition built by a pair. The lacking links are students' initial propositions that are not constructed by their partners, while the

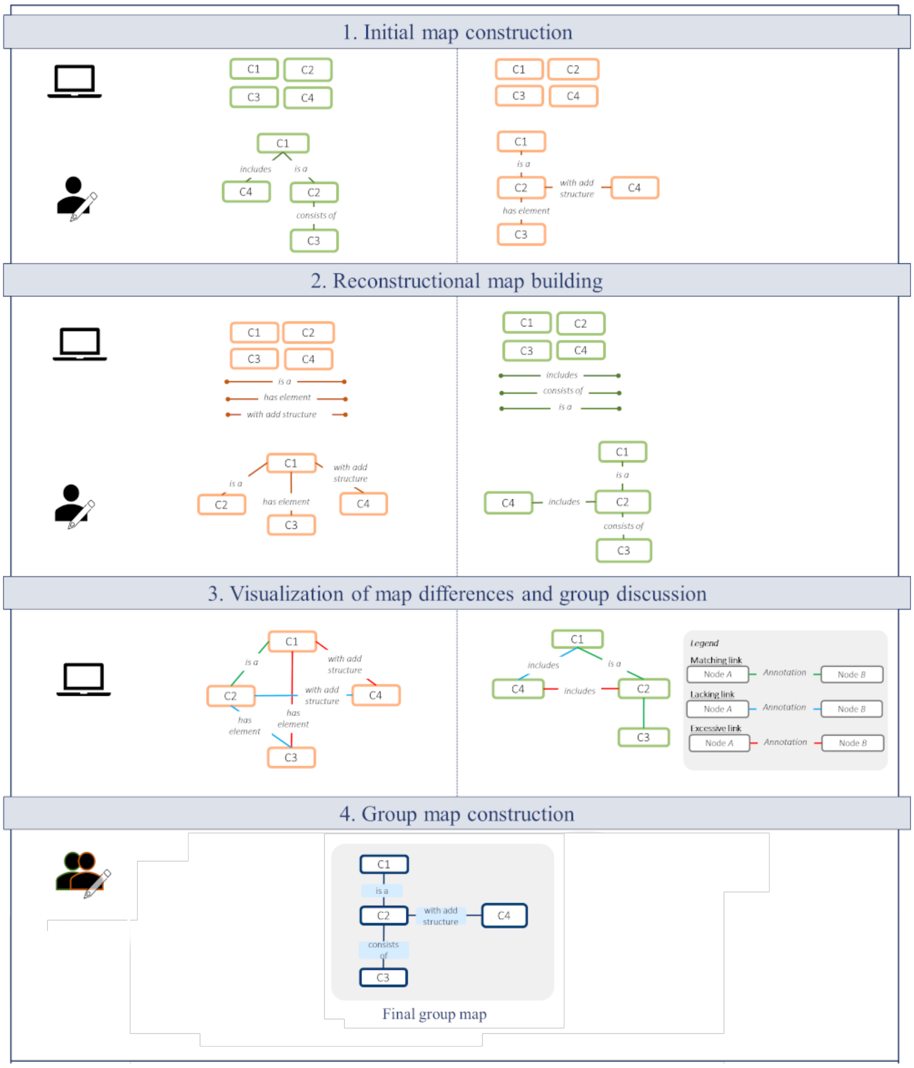

Figure 3.1: Illustration of collaborative concept mapping with Reciprocal Kit Build

excessive links are the propositions built by their partner but not exist in the initial maps. Both lacking and excessive links depict dissimilarities of map organizations. By looking over the difference map, individuals can reflect on their representation and explore different perspectives of their partners. The difference map, as a boundary object, presents anomalous information which is expected can trigger the group members to negotiate and integrate different meaning into a joint solution (boundary crossing).

b Group map construction.
Each group is requested to build a single group map as a collaborative product. While they are constructing the map, the KB system will display suggestions based on the integrated matching, lacking, and excessive links to help them to reach a consensus.

3.2 Participants and context of the study

The participants of this study was Computer Science (CS) students from a large public university in Indonesia ($n = 44$). Since the students were belong to the Faculty of Computer Science, more male students were included in this research ($n = 32$). Most

Figure 3.2: The classroom settings during the experiment

participants were freshmen ($n = 39$) in their second semester. They worked in groups of two, which were freely selected by the students so that they could work on the task conveniently. When students worked in a small group, they exhibited structures and leadership to sustain the continuity of the discourse and regulated their cognitions more than in a general class discussion (Junus, Sadita, & Suhartanto, 2014). Randomization of group members would be necessary to ensure the fairness of the treatment for all participants, however, based on suggestions from the responsible class teacher, the students were allowed to choose their own pair so that they would not be reluctant to collaborate.

This study was carried out on a core subject in Computer Science and Information System major named Linear Algebra which is a substantive core subject for undergraduate students. However, since the experiment was not conducted on its regular term, only one course was offered. This course provides students with the skill to solve problems related to vector and matrix algebra, as well as to develop mathematical reasoning skills (clarity, consistency, and logic). Problem-solving skills are essential to advance learning in CS-related topics. To achieve these learning outcomes, the teacher implemented the constructivism and student-centered learning approach during the 14 weeks course period. Both face-to-face and online courses were utilized as the learning environments. The students were engaged in various collaborative learning activities such as online discussion, think-pair-share, and jigsaw technique. A preliminary study of students' preparedness level in the computer-based learning environment from the previous classes revealed that students had a good technological competency, a moderate competency in interaction with learning content, but lacked interaction skills with their learning community (Junus, Santoso, Sadita, R-Suradijono, & Suhartanto, 2017). Therefore, the use of concept maps for expressing students' ideas and as a common ground during discussion aligned with the teacher's previous challenges on similar classes. Moreover, the students were familiar with map building concepts, since the teacher had modeled concept map creation, as well as asked the students to create their maps after she finished a topic.

The experiment was conducted in a laboratory where students might choose to use the provided computers or their laptops. The students were placed side by side in pairs (Figure 3.2). The results of this experiment were accepted as a part of the mid-term exams. A single group study was employed in the class since the results will affect the final grades of the students who completed the course.

In this study, students were requested to create a concept map individually and collaboratively. There were two lessons covered in the concept map, which are General Vector Space and Inner Product Space. Some learning objectives of these courses were as follows: students can explain general vector space, identify a set that is a vector space, and explain the definition of inner product function and inner product space.

During high school, the students became familiar with the concept of the vector in R^2 and R^3, but not in a more abstract space such as matrices or differential functions over $[a, b]$ space. After completing these topics, students were expected to do accommodation from the concept of a vector as an entity with length and magnitude, to a vector as

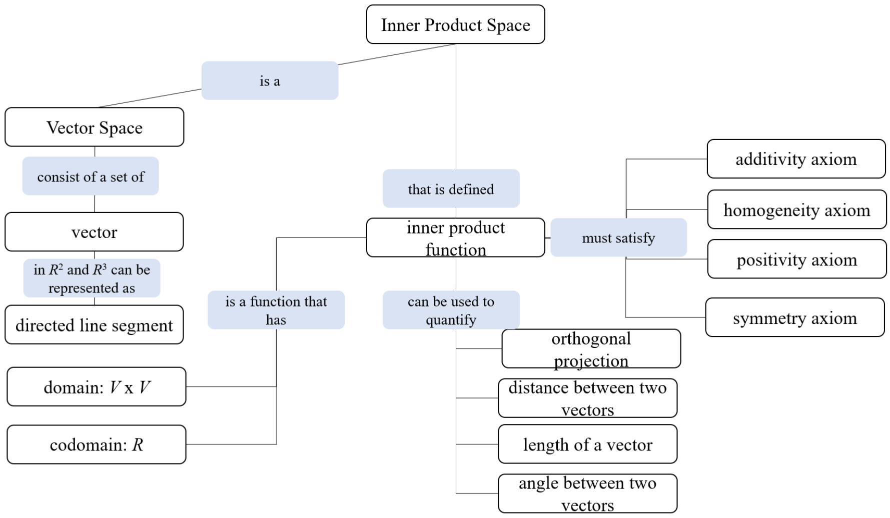

Figure 3.3: The expert's map

an element of vector space with the length and magnitude that calculated based on the defined inner product space. Students were also expected to understand that an inner product function is a function that maps $V \times V$ to R and must satisfy the following four axioms: additivity, homogeneity, positivity, and symmetry. The axioms are preconditions for defining an inner product function. It should be attached to the function, not to a space V.

Before giving assignments to the students, the teacher wrote a concept map that involved essential concepts in these courses. It consisted of fifteen nodes and fourteen links (Figure 3.3). The nodes were extracted and became predefined nodes for the students. The students had to find the relationships between those concepts (nodes) and provided linking words by themselves. The nodes were as follows: vector, Vector Space, Inner Product Space, directed line segment, additivity axiom, homogeneity axiom, positivity axiom, symmetry axiom, domain: $V \times V$, codomain: R, inner product function, orthogonal projection, the distance between two vectors, length of a vector, and the angle between two vectors.

3.3 Timeline of activities

During the experiment, the students used a web-version of the RKB system (Figure 3.4). Before the session, a video tutorial on how to use the system was presented to the students. A brief tutorial about concept mapping activity and how to create a simple map with the KB system was provided at the beginning of the experiment to ensure they were familiar with the assignment and the system.

The experiment was administered for about two hours and divided into two phases: individual phase and collaborative phase (see Figure 3.5). The students created an initial map phase (25 minutes) and reconstructed a KB map, given a set of unconnected nodes and links (kit) from their partner's maps (20 minutes), in the individual phase. They conducted a discussion facilitated by visualization of the similarities and differences between the two maps (10 minutes) and created a group map collaboratively (30 minutes) during the collaborative phase. Figure 3.5 depicts the sequence of learning activities during experiment. At the first individual phase, the students received predefined concepts (nodes) and were required to define the links (connection) between those concepts which enabled them

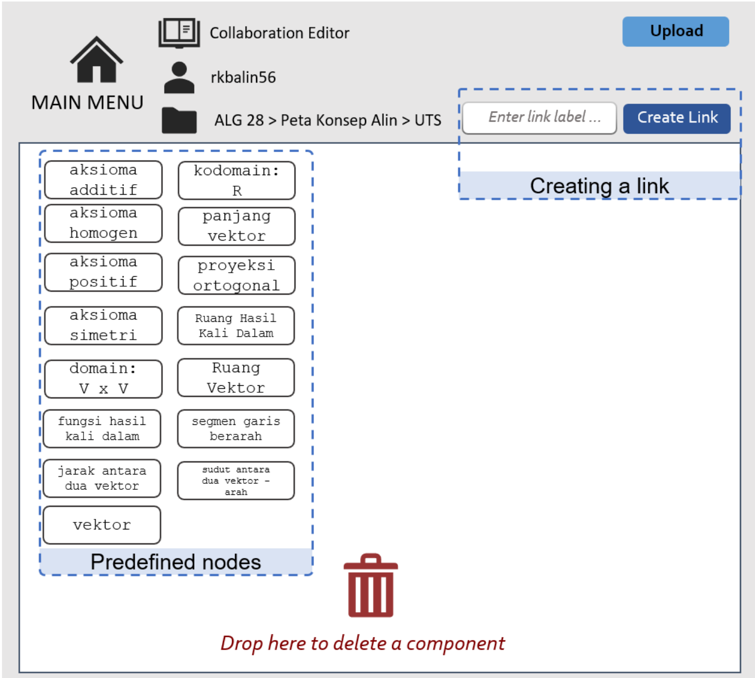

Figure 3.4: The user interface to create an individual map or a group map

to express their own understanding. Next, a set of unconnected nodes and links extracted by the system from each individual map was presented to their partners. Each student was then requested to build a new map, based on those components, which is called the KB map. After this reconstruction activity, the system performed a propositional-level exact matching to identify the similarities and differences between the initial map and the KB map. Afterward, each group conducted a discussion guided by difference map visualization, consisting of matching links, excessive links, and lacking links. Subsequently, to finalize the learning activity outcomes, each group constructed a single concept map collaboratively. The latest phase demanded more time since several groups needed extra time to conclude their final works, while some others had finished their task earlier.

Other learning resources such as course slides, the Internet, or textbook were open to the students and they were allowed to read and use them. Given initial nodes, students were told that they did not have to use all available nodes. The availability of the initial nodes served as key concepts that enabled participants to brainstorm other related concepts and proceed more efficiently (Gao, 2007).

After the experiment, the teacher provided feedback to students in the classroom. During the feedback session, the teacher explained the most common mistakes that appeared in the maps and showed some examples of the correct propositions. The feedback session was valuable because the students were informed of their misconceptions, and they learned how to build a good concept map. This session was held within 30 minutes.

3.4 Collected data

The RKB system recorded all initial maps, KB re-constructed maps, and group maps through a web-based system. As in a common classroom, the teacher evaluated the students' initial and group maps to identify the changes in quality. The KB maps use to confirm group understanding as a common ground for group discussion, therefore it was not graded. The students reviewed the similarities and differences between the initial

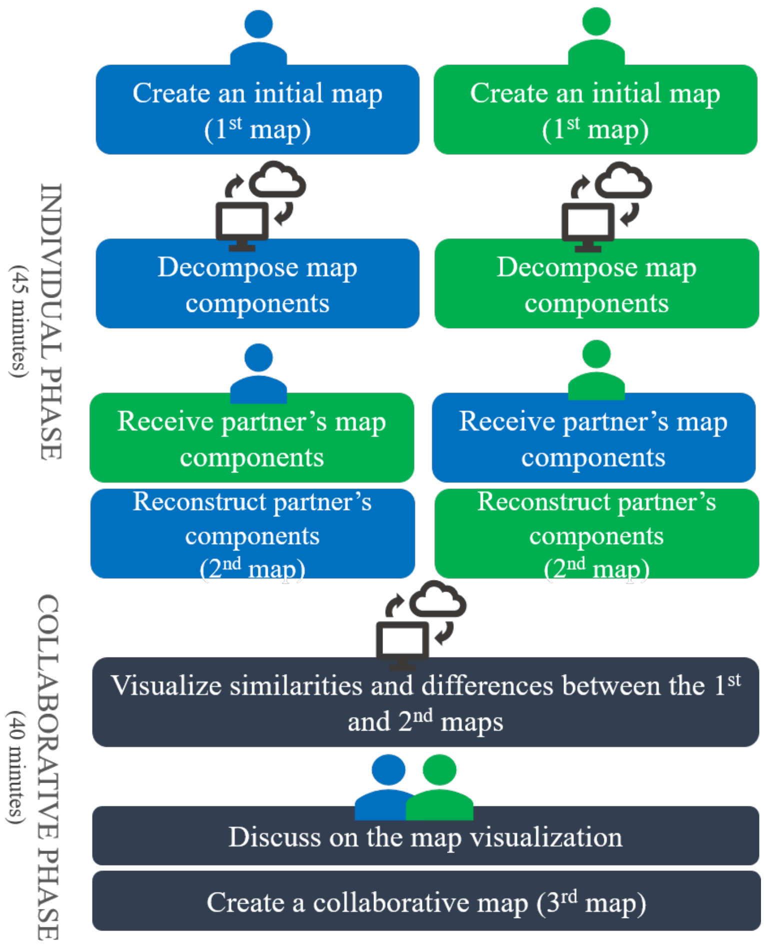

Figure 3.5: Sequence of learning activities

maps and reconstructed maps in the KB analyzer.

Chapter 4

RKB evaluation on collaborative products and students' perspective toward the activities

Summary

One strategy for improving the quality of students' explanations during CCM is to enable them to externalize their thinking privately, beforehand. Though some studies have suggested the inclusion of an individual preparation phase before CCM, only a few studies have provided a means for sharing individual knowledge. Increased awareness of a partner's understanding is essential in reducing miscommunication and improving the efficiency of the shared knowledge construction process. While existing studies propose that the RKB approach allows students to externalize their thinking and comprehend others' representations before collaboration, they have yet to evaluate the approaches to building group knowledge. This chapter presents an evaluation of group outcomes after students have participated in the RKB approach. It also analyzes how students change their propositions as they go from the individual to the collaborative phase, based on the visualization of the difference maps provided by the RKB system. During the research activities, students' perceptions are examined to measure the effectiveness of the approach from the viewpoint of the participants. The findings demonstrate that the RKB proves a promising strategy for learning in a collaborative context, despite some limitations in the practical classroom experimental settings.

4.1 Introduction

Previous research on collaborative concept mapping has extended the prior activity by creating an initial design of a concept map individually to trigger more questions and conflicts among learners (van Boxtel et al., 2000). This individual preparatory phase contributed to promoting awareness of own understanding and limitations, better explanation, and more elaboration (de Weerd et al., 2017; Gracia-Moreno et al., 2017; van Boxtel et al., 2002). However, learners also faced difficulty in integrating different ideas while creating a map collaboratively in a public space. In a study conducted by (Gracia-Moreno et al., 2017), more than half of the individual nodes were not transferred to the group public space, and the students were in tendency to refuse other ideas through online medium without asking for confirmation.

Table 4.1: Type of proposition error

Type of error	Description and example	Minus point
Fatal error	The students did not draw an essential link between the two nodes. The students created a wrong definition, e.g., the vector was defined as a directed line segment; the domain and codomain were linked to the inner product space/general vector space, not to the function; a vector space was defined as a subspace of an inner product space.	-10
Moderate error	The students connected a partially incorrect relation, e.g., the measurement-related nodes were connected to the vector and not to the inner product function; the axiom-related nodes were connected to the inner product space, not to the inner product function.	-5
Minor error	The students described partially incorrect linking words, but the relation was correct, e.g., a 'must' word was not included when defining a relation to the axioms	-2

The study proposes an approach to see the perspective of others before co-creation of concept map by reconstructing the partner's map and discussing the similarities and differences of two maps with the RKB system (Wunnasri et al., 2018a). After students externalize their thinking and understand the partners' perspectives, they are expected to build a shared-understanding and find a better solution for the problem task. The purpose of this study is to identify the effect of the RKB approach on collaborative concept mapping in a practical classroom. A Linear Algebra class is selected as the study subject since the class implemented various collaborative learning approaches for both in-class and online activities.

Research questions

The research questions of the study are as follows: "Does the RKB approach affect co-construction of knowledge with concept maps?" If so, to what extent? The study focuses on identifying the effectiveness from the end-products (collaborative maps), the patterns of map changes from individuals to groups, and the perceptions of the students while following the learning activities (Sadita et al., 2018).

4.2 Data analysis

4.2.1 Concept map scoring

The teacher developed a grading rubric to evaluate students' concept maps that used the expert's map as a criterion map (Osmundson, Chung, Herl, & Klein, 1999). The teacher categorized the types of information that should be included in the map, not merely a propositional-level matching. Therefore, it did not rule out the possibility that there is a variation on the map structure or the linking words which presented similar information (Chung, O'Neil Jr, & Herl, 1999). This scoring procedure involved comparing the similarities between students' produced maps and the expert's map, regarding the map contents and structures, which also has been practiced in other concept mapping studies (Chiu, 2004; Chiu, Huang, & Chang, 2000; Chiu, Wu, & Huang, 2000; Kinchin, De-Leij, & Hay, 2005). Such a scoring approach is reliable to measure domain-specific knowledge with a strong positive correlation to other content knowledge measures such as writing task (Herl, Baker, & Niemi, 1996).

Moreover, the teacher has considered students constructed propositions when finalizing the rubric. A full score was given to the map which contains all relations with correct linking words. A zero score was given to any proposition when the essential link (relation) was unavailable, or the linking words were not defined correctly. Every mistake will get a penalty based on the error type (Table 4.1).

4.2.2 Proposition similarity

Every student constructed a concept map three times, both individually and collaboratively. The study identified how students transfer their individual propositions to form group propositions. A propositional-level matching was utilized to identify the similarity between these propositions. First, the same relationship (connecting line) between the individual maps, KB maps, and group maps was identified. If both maps had the same connecting line, the linking words were taken and pre-processed by normalizing the text to lower case, removing punctuations, and stemming. Next, cosine similarity matching between the represented vectors of the linking words was applied to finalize the process. The same linking words means that they had a similarity score of 1.

4.2.3 Students' perspective toward the activities

After the experiment, a survey questionnaire was conducted to examine the students' perspectives on the RKB approach for creating a collaborative concept map. The questions were designed based on the preliminary results of the experiment. The survey covered items regarding the perspectives of the students on the task itself (e.g., attractiveness and stimulation scales) and the system used (or non-task; e.g., perspicuity scale). The questionnaire scales were adopted from the User Experience Questionnaire, an Indonesian version (Laugwitz, Held, & Schrepp, 2008; Santoso, Schrepp, Kartono, Yudha, & Priyogi, 2016). Since the aim of the study was to examine the perceptions of the students on every stage of the study approach, only three representative items were selected which were repeated for each stage (Figure 4.1). The final sub-scales of the study consisted of 15 close-ended items (Table 4.2, appendix A), where students were requested to rate the response set from 1 to 7 scale (left-to-right), and answer open-ended questions. The six open-ended questions were given to uncover the positive and negative experiences of the students during the experiment (e.g. "*Mention the most interesting moments encountered while you were asked to create a concept map from your friend nodes and links*", "*Mention (if any) any obstacle encountered when you were asked to create a concept map from your friend nodes and links*"). All questionnaire items had been face-validated by the teacher before distribution to the students. Cronbach's alpha coefficients were 0.74, 0.84 and 0.77 for attractiveness, stimulation and perspicuity subscales, respectively, showing good internal consistency.

KB for information elicitation from the group partner

	1	2	3	4	5	6	7	
annoying	O	O	O	O	O	O	O	enjoyable
inferior	O	O	O	O	O	O	O	valuable
complicated	O	O	O	O	O	O	O	easy

KB for understanding ideas of the partner

	1	2	3	4	5	6	7	
annoying	O	O	O	O	O	O	O	enjoyable
inferior	O	O	O	O	O	O	O	valuable
complicated	O	O	O	O	O	O	O	easy

The process of expressing ideas in the form of a concept map

6. Mention (if any) any technical and non-technical difficulty encountered while you were using Kit Build to express ideas in the form of a concept map?

The process of exchanging nodes and links with a partner

7. Mention the most interesting moments encountered while you were asked to create a concept map from your friend nodes and links.

8. Mention (if any) any obstacle encountered when you were asked to create a concept map from your friend nodes and links

Figure 4.1: A sample of closed- and open-ended questions. Full items are available in appendix A

4.3 Results

4.3.1 Overall group performance

This section of the study revealed how the quality of concept maps varied from the individual to the collaborative phase. The central tendency of individual and group concept maps was illustrated in Table 4.3. An paired-samples t-test was conducted to individual and group map scores. The results of the group maps ($M = 90, SD = 7.31$) showed increasing scores compared to individual maps ($M = 72.21, SD = 18.22$), $t(20) = 4.92$, $p < .01$. The observed standardized effect size was large (Cohen's $d = .87$). The standard deviation (SD) of group map scores also became lower, compared to individual scores. Some prior studies also used group maps to measure the effect of concept mapping in computer-supported learning on task performance (Chiu, Wu, & Huang, 2000; Stoyanova & Kommers, 2002).

Figure 4.2 depicts the differences between the averages of individual scores and the group map scores. A positive value shows an increasing score while a negative value represents otherwise. Eighteen out of 22 groups increased their scores, 3 groups got a similar score, while 1 group decreased their scores. Furthermore, the group ALG 18 was omitted from the analysis because the individual and group maps received full marks (100 points).

Changes of concept map quality were indicated from the decrease of errors in the group propositions (Table 4.4). The percentage of false propositions was reduced from 36% to 19%. Specifically, there was a change from the number of false propositions with fatal

Table 4.2: Closed-ended item categories

Context (category)	**Item code**	**Left**	**Right**	**Scale**
KB for expressing ideas/understanding of learning materials	`ExpIdea_A`	Annoying	Enjoyable	Attractiveness
	`ExpIdea_S`	Inferior	Valuable	Stimulation
	`ExpIdea_P`	Complicated	Easy	Perspicuity
KB for information elicitation from the group partner	`Elicit_A`	Annoying	Enjoyable	Attractiveness
	`Elicit_S`	Inferior	Valuable	Stimulation
	`Elicit_P`	Complicated	Easy	Perspicuity
KB for understanding the ideas of the partner	`Understand_A`	Annoying	Enjoyable	Attractiveness
	`Understand_S`	Inferior	Valuable	Stimulation
	`Understand_P`	Complicated	Easy	Perspicuity
KB for discussion with the support of visualization (figure) of the concept map differences	`Discuss_A`	Annoying	Enjoyable	Attractiveness
	`Discuss_S`	Inferior	Valuable	Stimulation
	`Discuss_P`	Complicated	Easy	Perspicuity
KB for integrating ideas in a group	`Integrate_A`	Annoying	Enjoyable	Attractiveness
	`Integrate_S`	Inferior	Valuable	Stimulation
	`Integrate_P`	Complicated	Easy	Perspicuity

errors. The reduction of fatal error propositions affected the increasing number of true propositions or moderate/minor error propositions.

Figure 4.3 shows an example of a set of maps generated by group ALG 12 during the individual and collaborative phases. The main difference between the individual maps is the Individual 1 connected "the measurements" concepts (e.g. length of vector, angle between vector, distance between vector, and orthogonal projection) to "the Inner Product Space", while the Individual 2 linked "the measurements" concepts to "the inner product function". The similarities and differences between the initial maps and the reconstructed maps were displayed to aid learners during the discussion. Finally, in the group map, they created the links as in the Individual 2's map, which is similar to the teacher's map (Figure 3.3).

Table 4.3: Descriptive statistics of individual- and group-map scores

Data	***M***	***SD***	***Min***	***Max***
Individual-map score	72.21	18.22	41.43	98.57
Group-map score	90	7.31	75.71	100

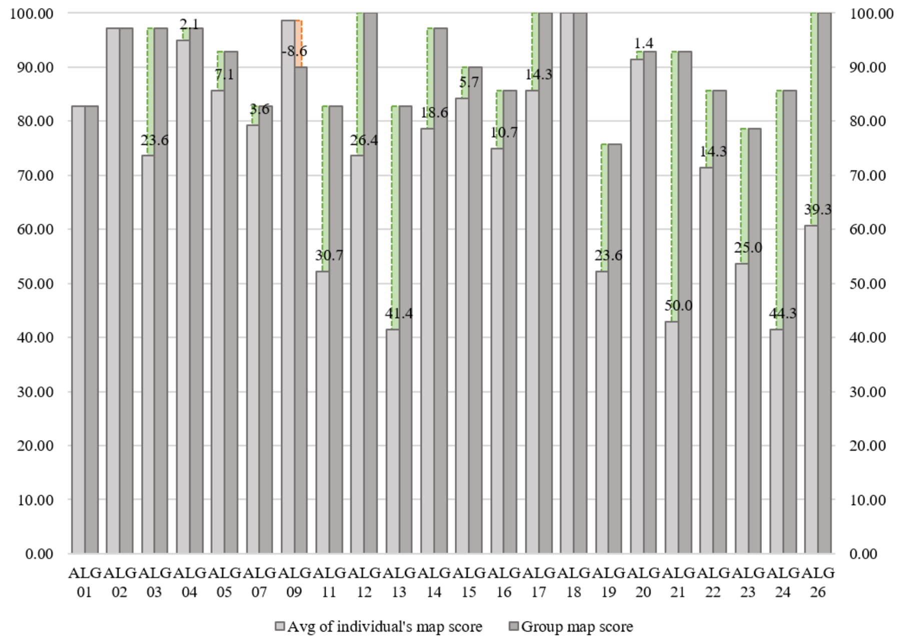

Figure 4.2: Scores from the average of individual and group maps, along with the differences between the two scores.

4.3.2 The pattern of students' propositions from the individual map to the group map

The process of knowledge co-construction was preceded by the externalization of individual knowledge and the sharing of ideas between partners through concept maps reconstruction. During the experiment, students did not receive any feedback from the teacher, but they could read other learning resources such as textbooks, course slides, or the Internet. This section explained the results obtained from students' propositions in every stage.

In the initial stage, all students wrote 582 propositions. From these propositions, the partner constructed 75.26% (n = 438) matching links and 24.74% (n = 144) lacking links. Based on the number of matching links, the students could reconstruct most of the propositions that originated from their partner's map, which implied that they could find the initial maps structures. The number of excessive links as many as 141, which means

Table 4.4: Distribution of correctness level in all individual and group propositions

Level of correctness	**Individual-map (%)**	**Group-map** (%)
The true proposition	64	81
The false proposition with a minor error	5	7
The false proposition with a moderate error	10	7
The false proposition with a fatal error	21	5

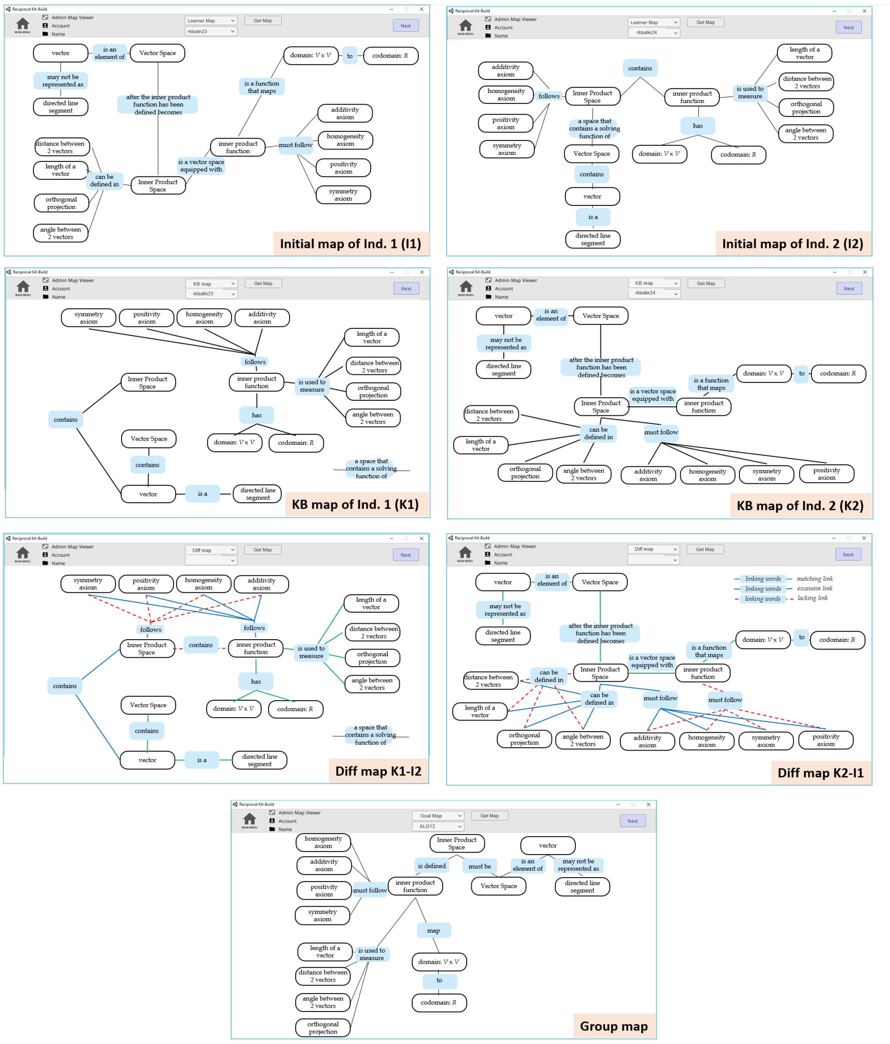

Figure 4.3: Sample of individual maps and group map generated by group ALG12

that there are three lacking links that did not become new propositions. The presences of the excessive and lacking links indicated that there were misunderstanding or disagreement between the group members.

It was then identified how students follow the visualization of the RKB links in the group propositions. When constructing a map collaboratively, all group members can determine whether they will use the same proposition as in the individual map, preserve the relation (connecting line) but modify the linking words, or create a different proposition. Figure 4.4 shows how the students adopted these reconstructed links to compose group propositions. Most matching links have included in the group propositions with the same connecting line (81%, n = 354). Most of the excessive links (60%, n = 84) were used to compose group propositions, but more than half of the lacking links were not used. The students modified the linking words from matching links, lacking links, and excessive links with portions of 56%, 22%, and 47%, respectively.

4.3.3 KB visualization and group performance on the task

As mentioned above, the individual propositions written in the initial and KB maps were generally adopted to become group propositions. In this section, the distribution of the cor-

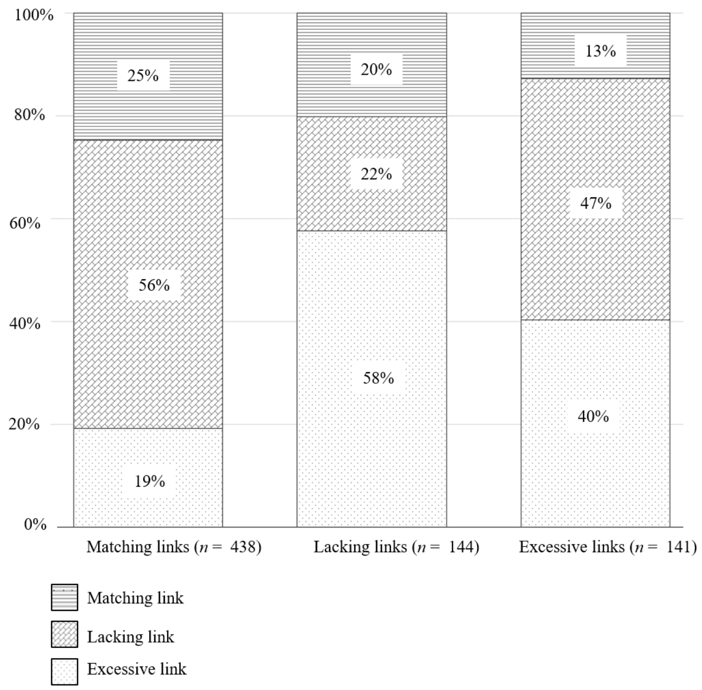

Figure 4.4: Proportions of the individual propositions taken from the system, with the matching, lacking, and excessive links, compared to the group propositions

rectness level of follow-up propositions in the group map was presented. Figure 4.5 reveals that these propositions are mainly correct. Students thought deeply about the propositions and found out the correct representation. Besides, Pearson's correlation analysis depicted that there was a moderate positive correlation between the score differences and the number of excessive links presented in the KB comparison map ($R(21) = 0.58, p < .01$).

4.3.4 Students' perceptions of the RKB approach

Figure 4.6 displays the results of closed-ended items. Overall, students considered that this activity was valuable, rather than inferior (stimulation scale), and more enjoyable, rather than annoying (attractiveness scale). Though the items related to perspicuity (complicated vs. easy) had the lowest ranks among others, the mean scores of those items were above 5.00. The perceptions of the students revealed that the KB was valuable for integrating ideas in a group, eliciting information from the partner, and discussing differences in ideas. Consistently, these three activities were getting the highest scores on the attractiveness scale. The students also found that discussion and integration were the most complicated parts, along with understanding the comprehension of their partners.

Based on the open-ended questionnaire, more than half of the students (60%) agreed that the most attractive phase was the phase when they could see the difference between the initial concept map and the reconstructed map (e.g., `I was glad to see the different way to connect the nodes by my friend`). The KB visualization of difference map also helped them to realize their mistakes (14.9%, e.g., `I realized if I have misconceptions or incorrect notions`) and made them understand the comprehension of their partner (8.9%, e.g., `I need to guess and try to understand perspectives of my friend's concept map.`). The KB links aided students in detecting alternatives perspectives as well (25.5%, e.g., `It is interesting to see the variety of my`

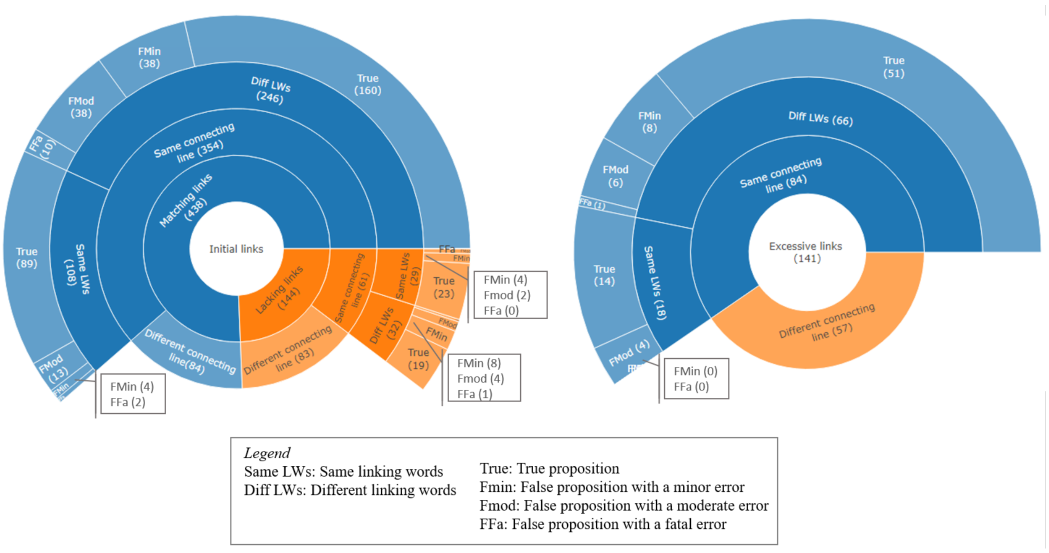

Figure 4.5: The number of propositions from the individual to the group maps were categorized by the link types in the KB-map, the similarity between the KB-map proposition and the group-map proposition, and the level of group proposition correctness

`friends' concepts and discussing it together.`). Some students reported that they faced difficulties in integrating different perspectives (15%), especially when they had many differences (6.4%). Some students felt like it was challenging to reach a consensus (12.8%, e.g., `It is difficult to determine who was the most correct.`).

4.4 Discussion

Following the proposed approach, students achieve high-quality group products. A possible factor contributing to better group outcomes is the interaction during discourse. The initial study of RKB presents that the pairs in the experimental groups demonstrate more exploratory talk when they discuss each other's ideas, compared to the pairs who were not using the system (Wunnasri et al., 2018a, 2018b). Exploratory talk is a type of talk in which partners engage in each other's ideas critically but constructively (Mercer, 1996). Students might actively dig for information when they agreed on what the other party says or offers arguments and look for alternative solutions when they disagree. Exploratory talk is considered the most educationally relevant type of talk that helps groups to reason together and increase individual learning gain (Wegerif, Mercer, & Dawes, 1999).

While creating an individual map is a method to express own understanding, the reconstruction activity is a method to understand the partner's point of view. Ideas exchange through the reconstruction of concept map components from a partner's map, and the discussion of difference maps could encourage understanding of the partner's representation (Wunnasri et al., 2018b). Comprehension of partner representation becomes visible. Even though the study of Engelmann and Hesse (2010) shows that the awareness of other knowledge might not necessarily affect the learning outcomes, it affects the process of knowledge construction to make it more effective because learners can reach consensus-building faster and no initial exploration is needed (Engelmann & Hesse, 2010). An awareness tool regarding knowledge of the collaborating partner allows social comparisons and guides activities. Learners approximate and integrate each other's perspectives, synthesize their ideas, and jointly try to make sense of a task (Nastasi & Clements., 1992).

The reconstruction does not only assist learners in understanding the partner's per-

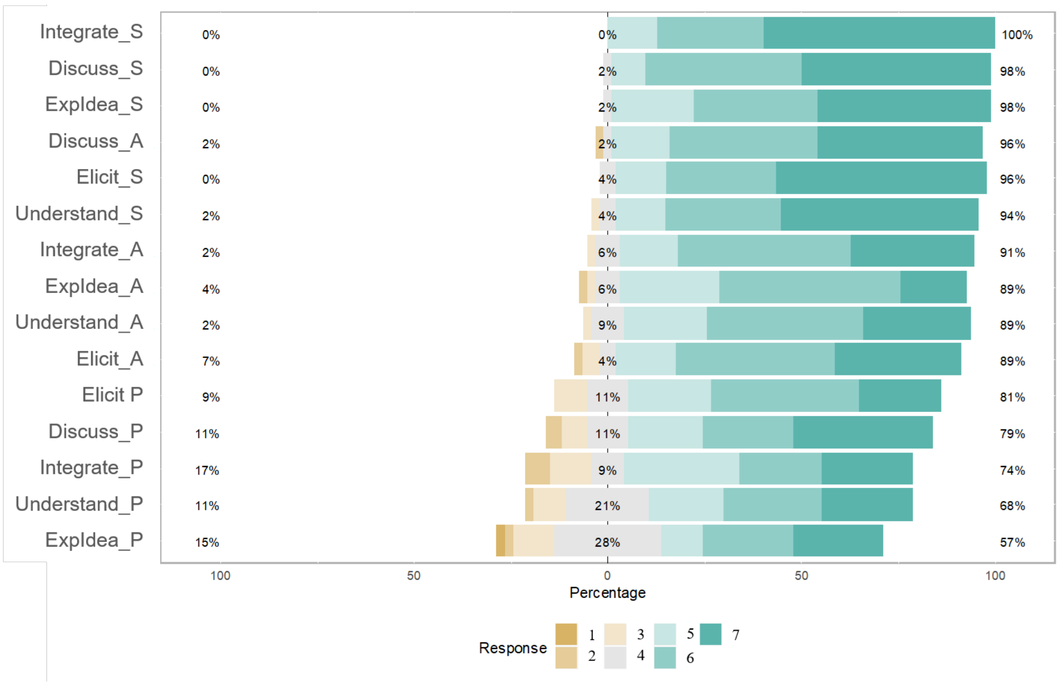

Figure 4.6: Summary of students' responses to the close-ended questions

spective but also reveals the similarities degree between a pair's prior knowledge. The correlation between the similarity of learners' individual maps and the number of matching and excessive links are .5283 and -.5205, respectively. These findings are consistent with the previous study results suggesting that the similarity of learners' map is reflected on their KB visualization (Wunnasri et al., 2018a). Moreover, some students agree that the reconstruction of the partner's kit is an interesting activity to find out the partner's comprehension (27%). They become aware of the similarities and differences between their perceptions (25%). They also find new ideas or different representations from a similar idea (14.9%).

The reconstruction activity also raised conflicts because the students have to review all map components and estimate the solution of their partners. After reconstruction, the system can illustrate a difference map to facilitate students' discussion. The students are then able to detect a discrepancy between their representations. Prior research demonstrates that irregular information triggers students to actively process and resolve conflicts, which subsequently compensates conceptual change and advancement of understanding (Chan et al., 1997). By showing a difference map, students may elicit relevant information from the partners, so that they can discuss to negotiate different understanding. This is a key step to resolve conflicts among group members. Finally, the creation of a join map is a means to integrate similarities and differences of individual knowledge and reach a consensus.

The results posit that, following the KB visualization, a clear majority of the students preserve the matching links, a moderate proportion of them maintain the lacking links, and more than half of the students preserve the excessive links in the group map with the portions of 82%, 42%, and 60%, respectively. The map scores gain has a moderate positive correlation with the number of excessive links. The students acknowledge the visualization from the KB map when they decompose a group map. Although the students keep the same link (relations), most of the linking words considerably differ in all types of KB links, which revealed that the students do not merely follow others' ideas, but also constructively build on the group shared knowledge.

In the KB approach, knowledge is made publicly accountable, and comprehension of others' perspectives is visible. Contrary to other approaches that can be only visible in the utterances (talks), comprehension and misunderstanding of partners' representation are not explicitly supported. The RKB is promising due to the reconstruction activity and the visualization of lacking and excessive links that could stimulate learners' progress on solving the task. By facing criticism, learners may be pushed to test multiple perspectives or to find more and better arguments for their positions (Chan et al., 1997). When building a consensus in a conflict-oriented manner, learners need to identify specific aspects of their peers' contributions and modify them or present alternatives. Thus, learners need to operate more closely in the reasoning of their peers when compared to a simple acceptance of peers' contributions (Chan et al., 1997). Prior studies indicate that active pursuit of resolving conflicts is necessary for the construction of knowledge (Kalishman et al., 2012; Roschelle, 1992; Roschelle & Teasley, 1995; van Boxtel et al., 2002). Both the visualization and clarification assist the discovery of discrepancies between individual knowledge representations, which provokes students to explain their reasoning and allows them to develop their resolution of differences through elaboration (van Boxtel et al., 2002). Learning effectiveness depends on the extent to which students share their learning; as a process of knowledge acquisition and creation through direct interaction (Stoyanova & Kommers, 2002).

The current findings show that after following the RKB activities most dyads can achieve high-quality group solutions and transfer their individual ideas, which are the representative forms of learning effectiveness at the group level as a whole and as an interaction between individual students and group achievements as stated by (Stoyanova & Kommers, 2002). Moreover, the students have also positively accepted the learning activities. The assessment of group performance is an important initial stage to identify the effectiveness of the RKB for collaborative learning. According to (Dillenbourg, 1999), the validity of group assessments can be understood in practical terms since the need for collaboration among professionals is increasing and any educational institution is required to improve the students' performance in collaborative situations. Furthermore, an investigation of learning effectiveness at the level of individual students and the interaction of group achievements with the individual post-collaboration outcomes is also interesting to uncover how the RKB approach affect conceptual change at the individual level.

Limitations of the study and directions for future studies

This study is the first attempt to explore the potential use of the RKB system in a practical classroom in Indonesia. A single group study is conducted to ensure fairness in a real classroom context. Future studies may conduct an experimental study in order to measure the effectiveness of the RKB approach compare to a common collaborative concept mapping approach with individual externalization and concept map sharing. A within-subjects study with counterbalancing and group randomization can be a potential alternative for further research. To evaluate the effects of collaborative activities on individual knowledge, students would be requested to build post-collaboration maps or answer a pre- and post-test as parts of the experimental activities in the future. Moreover, the use of RKB in collaborative learning settings is administered in a dyad. The issue of how to transfer this approach to more than two people would be another subject of future research.

Most students consider the RKB approach is attractive and stimulating, while the lowest items are related to perspicuity scale. This may be because the students' cognitive loads are rather high. It is suggested differentiating the individual and collaborative phase to reduce the students' loads. Some students also report several technical issues. The interface of the RKB system may require some improvements. Further, an analyzer that shows students' generated links might be useful to provide information about students' progress for the teacher.

4.5 Conclusion

This study investigates the use of RKB approach to support collaborative knowledge construction, extending previous collaborative concept mapping approaches (de Weerd et al., 2017; Engelmann & Hesse, 2010; F. Fischer et al., 2002; Gracia-Moreno et al., 2017) in two ways: by reconstruction of partner's kit and by the visualization of individual map differences. The study findings indicate that the combination of these activities supports learners to achieve high-quality collaborative products as in the previous collaborative concept mapping studies with individual externalization and knowledge awareness tool. The visualization of map differences acts as a guide during discourse which is reflected from the patterns of modifications from the individual, i.e. initial and reconstruction maps, to the group maps. Positive attitudes of the students toward the activities signify the usefulness and attractiveness of the learning activities. The proposed approach provides a means for sharing of individual ideas and discovers the divergence of knowledge that has not been utilized in other studies. Though the results from this initial study seem promising, to infer the generalizability of the proposed approach more experiments in different classroom contexts and settings should be conducted.

Chapter 5

The effect of individual knowledge differences to group collaboration

Summary

Collaborative learning requires a structured and open environment, where individuals can actively exchange and elaborate their ideas to achieve a high-quality, problem-solving solution. Though previous studies show the RKB proves promising in the promotion of productive discussion and achieving high-quality group products, how individual knowledge differences may potentially influence the effectiveness of collaboration has yet to be explored. This study aims to identify the effect of group composition on learning effectiveness, at the level of interaction between the individual and the group and at the level of the group as a whole. Our findings show that the transfer of an individual's shared and unshared knowledge is considerably high in all group conditions. Group composition does not significantly affect knowledge transfer and final group products; however, it may prompt learners to experience different perceptions toward the activities. The results are essential for practitioners, who intend to apply the RKB in their classroom, to determine the appropriate group setting.

5.1 Introduction

A central question of research and practice in computer-supported collaborative learning is how learners within a group influence each other and manage to converge regarding their knowledge. (F. Fischer et al., 2002; Weinberger et al., 2007). Convergence of knowledge is defined as occurring when the activities of two or more learners have an impact on those of their partners, which impact their own activities in turn (Roschelle, 1992). Jeong and Chi state that similarity of knowledge may be achieved because group members experience the same environmental and cultural conditions or collaboratively interpret a situation or solve a problem together (Jeong & Chi, 2007). We therefore, believe that the design of a learning environment, including activities and tasks, is a critical factor in obtaining knowledge convergence following a collaborative session.

Preconceptions and divergence in knowledge influence the benefits experienced by group members when learning collaboratively (Weinberger & Fischer, 2006). To promote the negotiation of perspectives towards shared understanding, prior studies on collaborative learning suggest the use of heterogeneous group composition (Johnson & Johnson, 1987; Webb, 2009; Weinberger et al., 2007). In a heterogeneous situation, we expected group members would constructively build on different ideas, thus promoting similarities of knowledge. While previous research confirms that nurturing group members to use available knowledge is beneficial in helping learners to attain knowledge convergence, unfortunately, it is also found that groups often neglect unshared resources–that is, knowledge and information that only a small number of the group possess or have access to (F. Fischer & Mandl, 2002). This emphasizes the need for a structured and open collaborative-learning environment where individuals actively exchange, build and elaborate the shared and unshared knowledge resources of the group.

The concept map has been widely employed in collaboration to facilitate idea generation, maintain shared focus and negotiate meaning (Basque & Lavoie, 2006). Utilizing a concept map during collaboration supports the collaborative-learning process (i.e. knowledge elicitation and negotiation), since the cognitive structure of learners is made visible and ready to manipulate(F. Fischer & Mandl, 2002). The use of a concept map to represent group-shared understanding has positively impacted learning achievements, both at individual and group level(Stoyanova & Kommers, 2002). At the individual level, the concept map allows knowledge to become more explicit and provides room for reflection and elaboration of cognition (Stoyanova & Kommers, 2002), while at the group level, the concept map promotes the establishment of common ground as a basis for building shared understanding among group members (Jeong & Hmelo-Silver, 2016; Roschelle & Teasley, 1995; Stoyanova & Kommers, 2002).

Though studies of collaborative concept maps show promising results, variations in learning activities have been encouraged to assist more productive interaction, such as including an individual-preparation phase or a sharing of the group members' concept maps before the collaborative session (Engelmann & Hesse, 2010; F. Fischer & Mandl, 2002). By adding the individual-preparation phase, each learner can develop their own understanding, which results in a better explanation of individual knowledge and more elaboration during discourse (F. Fischer & Mandl, 2002; Gracia-Moreno et al., 2017; van Boxtel et al., 2000). Sharing partners' knowledge structures beforehand has successfully increased awareness of others' knowledge, causing learners to focus directly on different perspectives (Engelmann & Hesse, 2010; Engelmann, Kozlov, Kolodziej, & Clariana, 2014). Active reviewing of group members' initial maps positively affects the broadness of group solutions to problems(Stoyanova & Kommers, 2002).

The current study has extended collaborative concept mapping with the RKB method. When RKB was put into practical use for collaborative concept mapping in a Linear Algebra class, almost all groups produced a high quality collaborative map and there was an association between difference map visualization and individual-to-group-score gain (Sadita et al., 2018). The same study presents how group maps changed according to the RKB visualization of different links; however, it did not investigate how individual differences in prior knowledge in each group may influence collaborative-learning effectiveness (e.g. transfer of knowledge, lost knowledge, group product) and the students' feelings about the learning process itself. This investigation is needed to draw a comprehensive understanding of the effectiveness of the KB approach, as well as to provide suggestions for practitioners who want to apply the KB method in the classroom environment.

Research questions

The present study aims to identify the effect of differences in group composition on learning effectiveness in two dimensions-i.e. interaction between group members and group achievement-based on measurements proposed by some previous studies (Khamesan & Hammond, 2004; Stoyanova & Kommers, 2002). To determine the homogeneity of group composition, we used the knowledge convergence measurement defined by (Weinberger et al., 2007), which distinguishes group knowledge equivalence and shared knowledge (Khamesan & Hammond, 2004; Stoyanova & Kommers, 2002). Furthermore, learners' perceptions of the learning activities were evaluated to find out their affective responses to

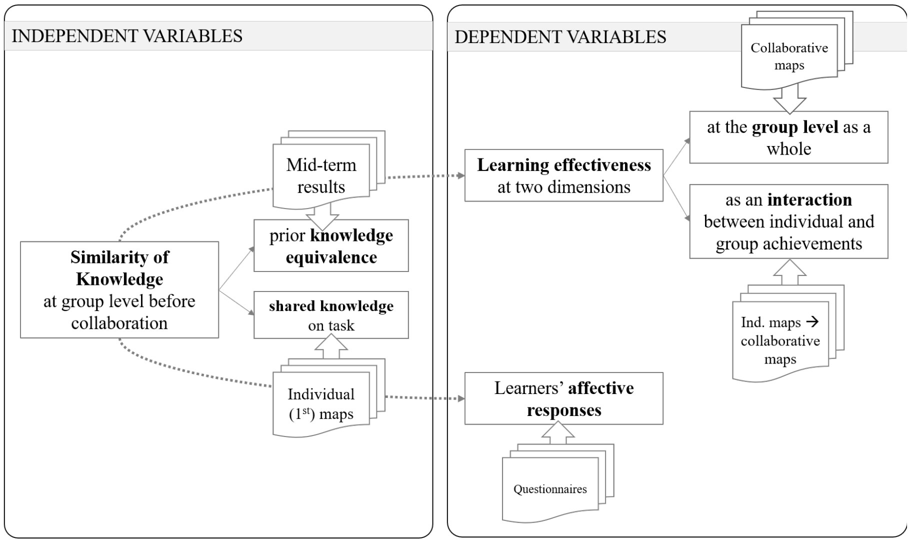

Figure 5.1: Variables involved in this study

different group compositions. The following research questions guide our study (Sadita, Hirashima, & Hayashi, 2019; Sadita, Hirashima, Hayashi, Furtado, et al., 2019, 2020):

(a) What are the overall patterns of knowledge transfer from individual-to-group representation?

(b) Does similarity of knowledge affect students' learning effectiveness in the two dimensions (i.e. interaction of individual members and group level), and, if so, to what extent?

(c) Does similarity of knowledge affect the experiences of participants in the study, and, if so, to what extent?

5.2 Data analysis

There are three variables in this study: similarity of knowledge, learning effectiveness and learners' affective responses. Similarity of knowledge was determined based on the students' mid-term scores and their individual (first) maps; learning effectiveness was measured from the collaborative (final) maps and the similarity of contents between the individual and collaborative maps; the affective responses of the learners were captured through a questionnaire. Figure 5.1 depicts the relationships between all variables as well as the corresponding data source.

5.2.1 Similarity of knowledge

Weinberger, Stegmann and Fischer conceptualize knowledge convergence as knowledge equivalence and shared knowledge, which can be evaluated prior to, during, or after collaboration (Weinberger et al., 2007). In order to identify similarity of knowledge within each group, we used two types of measurements: prior-knowledge equivalence and shared knowledge. Knowledge equivalence refers to learners in a group possessing a similar degree of knowledge related to a specified subject, regardless of the specific concepts constituting knowledge content (Weinberger et al., 2007), while shared knowledge alludes to the knowledge of specific concepts that learners within a group have in common (Weinberger et al., 2007).

Table 5.1: Seven essential pieces of information included in the map and its possible substructure

No	Type of information	Possible nodes included in the substructure
1	An inner product space is a vector space with an additional structure called the inner product function	Inner Product (IP) Space – Vector Space (VS)
2	An inner product function takes each ordered pair in a vector space V to a number in R	IP function – domain: $V \times V$ & codomain: R
3	An inner product function is a function which satisfy all following axioms: additivity, homogeneity, positivity, & symmetry	IP function – 4 axioms: additivity, homogeneity, positivity, & symmetry
4	Vector is an element of a vector space V	vector – IP Space (if the IP Space is connected to VS); or vector – VS
5	By using the inner product function of an inner product space, we can measure the orthogonal projection of a vector, the distance between two vectors, the length of a vector, and the angle between two vectors	IP Space – the measurements: orthogonal projection, distance between two vectors, length of a vector, angle between two vectors; or VS – the measurements
6	An inner product space is a vector space with an inner product function	IP Space – IP function; or VS – IP function (if the VS is connected to the IP Space)
7	Only a vector in R^2 and R^3 that can be represented as a directed line segment, but not a vector in higher dimension	vector – directed line segment; or the directed line segment node is not connected to any other nodes

Note:

- – represents a link / connection between nodes / concepts
- the linking words may have more variation

Table 5.2: Sample of knowledge distribution in a group

No	Substructures	Student A's map	Student B's map	Group map
1	Inner Product (IP) Space – Vector Space (VS)	o	o	o
2	IP function – domain: VxV & codomain: R	x	x	o
3	IP function – 4 axioms	o	x	o
4	Vector – IP Space or VS	o	o	x

Note:
o : the substructure was available and correct
x : the substructure was not available or incorrect

The prior-knowledge equivalence scores were calculated from the results of a mid-term test conducted a few days before the experiment. The questions in the test covered essential introductory materials required to understand the main topic in the concept map, but did not include the conceptual knowledge that could be drawn in map form, such as the relationships between concepts. Measures of dispersion were used to analyze differences in prior knowledge, as in a prior study (Weinberger et al., 2007). First, individual mid-term tests were evaluated by the teacher. Second, the standard deviation between the scores and the average scores in each group was calculated. Last, the standard deviation was divided by the mean score to measure the coefficient of variation as a prior-knowledge-equivalence score.

We assessed shared knowledge quantitatively from the individual maps using the approach proposed by (Weinberger et al., 2007). First, the teacher defined the essential information to be included in the maps. Then, she listed all possible and common substructures from all student-generated maps. A substructure may consist of two or more connected nodes (concepts) that convey only one essential piece of information (see Table 5.1). Variation in substructures was also deemed acceptable, depending on the linking words written by the students. Second, the teacher marked whether a student's map exhibited any of the essential information or not. A maximum of seven important substructures was expected to appear in the maps. Third, if a pair of learners shared the ability to apply a specific concept, we added a shared-prior-knowledge score of 1. Finally, we normalized the score by dividing it by the group mean value. In addition, we counted the number of unshared substructures at the individual level to identify information possessed only by a single member.

Table 5.2 provides a sample of knowledge distribution in a group. Following the above procedure, the individual-knowledge scores of students A and B in Group 01 were 3 and 2, respectively, based on the number of correct substructures, resulting in a mean of 2.5. Group 01 achieved a shared-knowledge value of 2 because both members were able to draw the first and the fourth substructures correctly. Consequently, the normalized shared-knowledge score of this group was 2 / 2.5 (i.e. 0.8).

The normalized prior-knowledge-equivalence score and shared-knowledge score were applied to categorize the group. Groups with normalized prior-knowledge-equivalence scores of less than 0.2 were categorized as high-knowledge-equivalence groups, and groups with normalized shared-knowledge scores of more than 0.7 were categorized as high-shared-knowledge groups. The prior-knowledge-equivalence scores provided the different levels of individual performance on prior relevant topics, while the shared-knowledge scores were more specific to knowledge related to the task itself.

5.2.2 Learning effectiveness measurements

To measure learning effectiveness, this study employed collaborative concept map-analysis methods proposed by Khamesan and Hammond (Khamesan & Hammond, 2004), which extend the initial works of Stoyanova and Kommers (Stoyanova & Kommers, 2002). Khamesan and Hammond divide learning effectiveness into three levels: the level of individual learning, the level of a group as a whole and the level of interaction between individual and group. This scoring system achieved a high inter-rater reliability score, with correlations between r =.52 and r = .99, for most of the categories. Since our collected data consists of both students' individual maps and the group map, we only evaluated effectiveness in two dimensions: at the group level as a whole and as an interaction between individual and group achievements. The following measures are used in this study (see Figure 5.2):

- Individual-to-group transfer of shared knowledge (TSK_{AB}): the number of substructures shared by both individual maps and transferred to the collaborative map. The

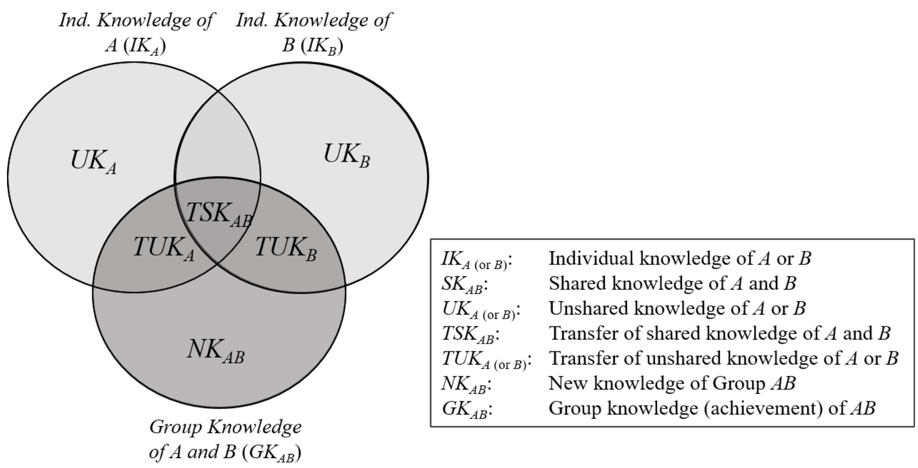

Figure 5.2: Illustration of learning effectiveness analysis

score was normalized with the number of shared substructures.

- Individual-to-group transfer of unshared knowledge ($TUK_{A(orB)}$): the number of unshared substructures in each individual map and transferred to the collaborative map. The score was normalized with the number of unshared substructures.
- Individual-to-group transfer ($TK_{AB} : TSK_{AB} \cup TUK_A \cup TUK_B$): the total number of transferred substructures from individual maps to the collaborative map. The score was normalized with the number of shared and unshared substructures.
- Lost knowledge ($LK_{AB} : (IK_A \cup IK_B) \setminus TK_{AB}$): the number of individual substructures not transferred from individual maps to the collaborative map.
- Group creativity (NK_{AB}): the number of new substructures in the collaborative map that were not included in both individual maps. The score was normalized with the number of unknown substructures.
- Group achievement (GK_{AB}): the number of substructures in the collaborative map. The score was normalized with the maximum number of possible substructures.

After normalization, each score interval is between 0 and 1.

Based on the sample of knowledge distribution depicted in Table 5.2, substructures (1) and (4) were the shared knowledge about the task of Group 01, while substructure (3) was the unshared knowledge of student B, and substructure (2) was the unknown substructures of Group 01 (ignorance). During collaboration, the students wrote substructures (1) to (3) correctly, so we regarded those substructures as group knowledge. Specifically, substructure (1) was considered as the individual-to-group transfer of shared knowledge, substructure (2) was categorized as new knowledge, and substructure (3) was categorized as the individual-to-group transfer of unshared knowledge. As Group 01 members did not write substructure (4), it was categorized as lost knowledge.

5.2.3 Learners' affective responses

We conducted a survey to capture the experiences of learners while participating in the experiment. The questionnaire consisted of 15 closed-ended items related to attractiveness, stimulation and perspicuity subscales, which were adapted from an Indonesian-language version of a user-experience questionnaire (Santoso et al., 2016). The students rated the

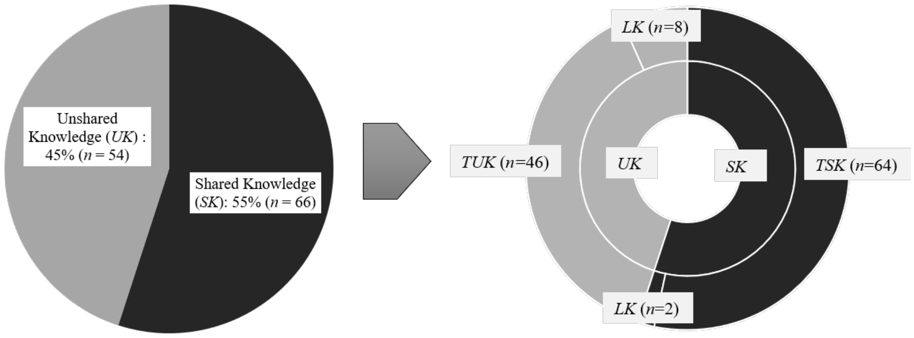

Figure 5.3: Distribution of shared and unshared knowledge in individual maps prior to collaboration (left) and distribution of individual knowledge transferred to collaborative maps in all groups (right)

items on a Likert scale (from 1 to 7). Six open-ended questions were asked to capture the positive and negative experiences of learners at every step of the collaborative learning activities. All questionnaire items had been face-validated by the teacher before distribution to the students. Cronbach's alpha coefficients were 0.74, 0.84 and 0.77 for attractiveness, stimulation and perspicuity subscales, respectively, showing good internal consistency.

5.3 Results

5.3.1 Overall patterns of knowledge transfer

During the first phase of the experiment, 82% ($n = 120$) of the essential substructures were written in the individual maps. Fifty-five percent of those written substructures are shared knowledge (Figure 5.5). As much as 92% of the shared and unshared knowledge is also seen in the collaborative maps, the remainder becoming non-transferred (lost) knowledge. Almost all shared knowledge is transferred to the collaborative map, while the percentage of neglected unshared knowledge is 15% ($n = 8$) of total unshared knowledge. Fourteen groups extended their group maps with new information (substructures) that did not exist in the individual maps ($n = 8$). The amount of unknown information (ignorance) in the collaborative maps decreased, from 18% to 13%.

5.3.2 Learning effectiveness at the group and interaction level

Figures 5.4 and 5.5 display the distribution of knowledge transfer and group creativity (new substructures) among different conditions regarding prior-knowledge-equivalence and shared knowledge on the individual concept maps. Since the data do not follow a normal distribution, only median and range values are presented in the figures. The amount of shared and unshared knowledge transfer from all groups in all conditions remained at the same level (similar median values), with differences in score distribution. The high-knowledge-equivalence groups have quite different scores, regarding transfer of knowledge, in comparison with the low-knowledge-equivalence groups. A similar trend is seen in the high- and low-shared-knowledge groups, in terms of their transfer of shared and unshared knowledge. In general, the individual-to-group transfer of knowledge score in high- and low-shared-knowledge conditions exhibits the same median value and similar distribution.

We also investigated whether individual knowledge about the task affects group tendency to transfer unshared knowledge, by calculating the correlation between individual map score and normalized score for individual unshared-knowledge transfer. Results of

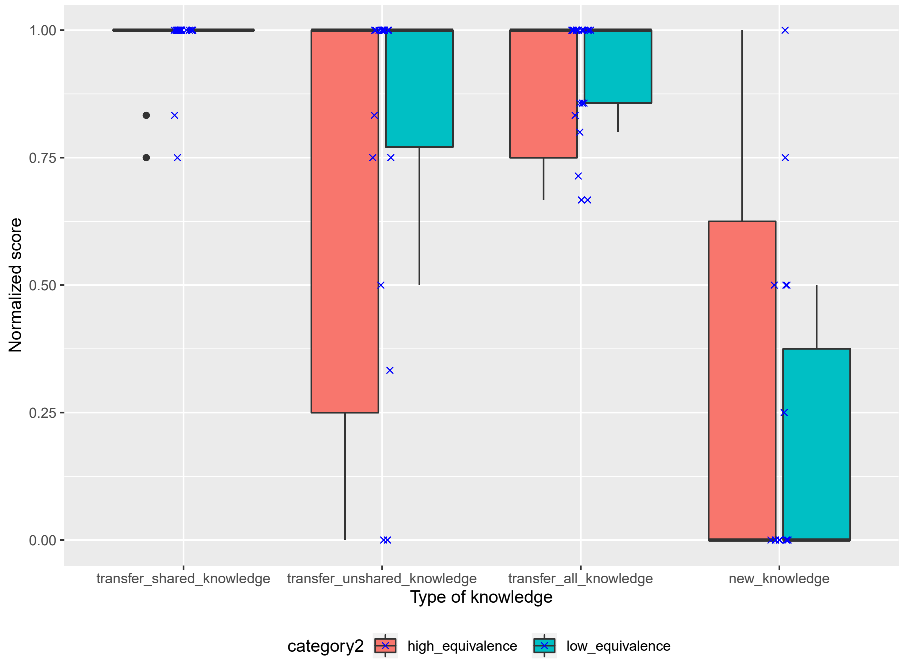

Figure 5.4: Distribution of knowledge transfer and new knowledge in high- and low-prior-knowledge-equivalence groups ($n = 11$ and $n = 10$, respectively)

the Pearson correlation indicate that there is no association between individual map score and amount of unshared-knowledge transfer, ($r(22) = -.060, p = .78$).

Based on the knowledge-equivalence scores, the group creativity scores in both conditions show similar median values, though the distribution is different. The high-knowledge-equivalence groups show more variation of group creativity score than the low-knowledge-equivalence groups. However, the low-shared-knowledge groups have higher new knowledge scores than high-shared-knowledge groups. The 14 groups who have new knowledge are similarly distributed in each condition ($n = 7$ each).

All collaborative map scores are in the range of 75-100 for all conditions ($M = 90, SD = 7.31$) and are higher than individual map scores ($M = 72.2, SD = 25.5$). On average, the low-knowledge-equivalence groups received 91.17 collaborative map scores ($SD = 7.22$), while the high-knowledge- equivalence groups received 88.71 scores ($SD = 7.95$). Additionally, the high-shared-knowledge groups earned 91.69 collaborative map scores ($SD = 5.99$), while the low-shared-knowledge groups received 88.14 scores ($SD = 8.81$). According to Welch's t-test, the group achievement scores do not differ significantly between low- and high-knowledge-equivalence conditions, $t(18.3) = -0.74, p = .47, d = 0.32$, 95% CI [-9.43 4.53], or between low- and high-shared-knowledge conditions, $t(15.6) = 1.07, p = .30, d = 0.48$, 95% CI [-3.50, 10.6], though there is dissimilarity of distribution among them (Figure 5.6). Some samples of the collaborative maps are illustrated in Figure 5.7 and 5.8.

5.3.3 Learners' affective responses

Figure 5.9 presents the distribution of the affective response scores among groups with different shared-knowledge scores. A Kruskal-Wallis rank-sum test indicates that there is a significant difference between the groups with higher similarity scores and lower similarity scores ($H(13) = 56.8, p < .001$). However, these differences, though significant, are small, which denotes that the learners in heterogeneous groups do experience positive feelings

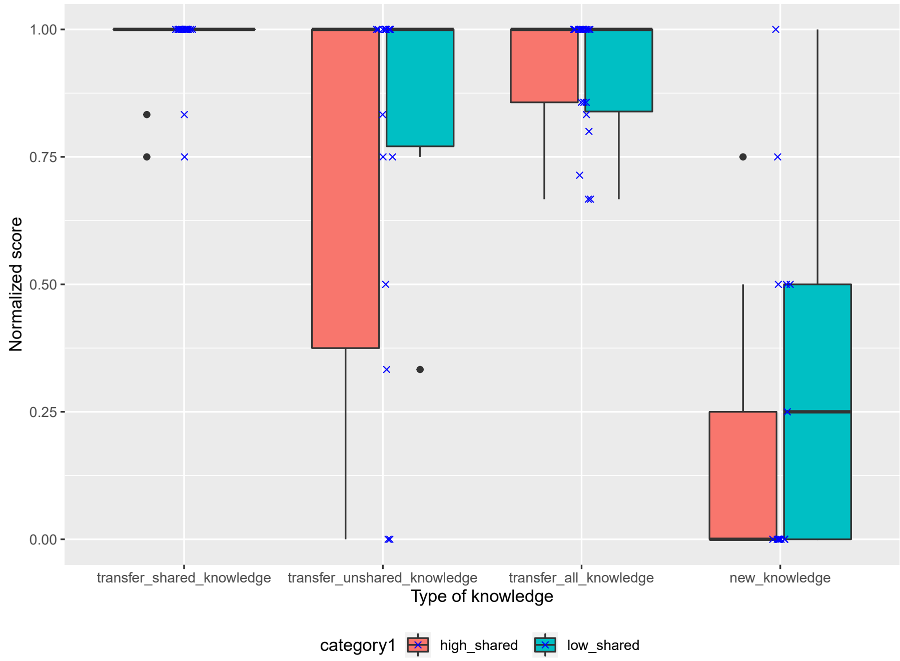

Figure 5.5: Distribution of knowledge transfer and new knowledge in high- and low-shared-knowledge groups ($n = 10$ and $n = 11$, respectively)

towards the activities, albeit less positive than those of learners in homogeneous groups. The stimulation subscale receives the highest rating, followed by the attractiveness and perspicuity subscales, respectively. From the open-ended questions, we found that some participants in both homogeneous and heterogeneous groups reported comparable on-task difficulties concerning dissimilarities of ideas or opinions, i.e.: "Difficult to read when the number of visualized differences is too many ($n = 6$)", "It was hard to read or understand the difference map ($n = 2$)", "It was difficult to integrate different opinions in order to reach a (group) consensus or determine which one is the correct representation ($n = 5$)", "The use of ambiguous links makes it hard to select the most suitable relation between two concepts ($n = 1$)".

5.4 Discussion

Collaborative concept mapping using the RKB approach allows learners to represent and manipulate individual cognitive structures and lets partners provide feedback after initial map reconstruction and difference map visualization. This activity provides an active means to review individual maps and to elicit new information. Access to distributed cognitive resources gained through reviewing learners' individual maps positively influenced the broadness of group solutions to problems (Stoyanova & Kommers, 2002). Consistently, our findings show that the amount of essential knowledge, which each group should have possessed, was increasing while students took part in the activities. The process of knowledge acquisition and creation through direct interaction had an impact on group-learning effectiveness (Stoyanova & Kommers, 2002).

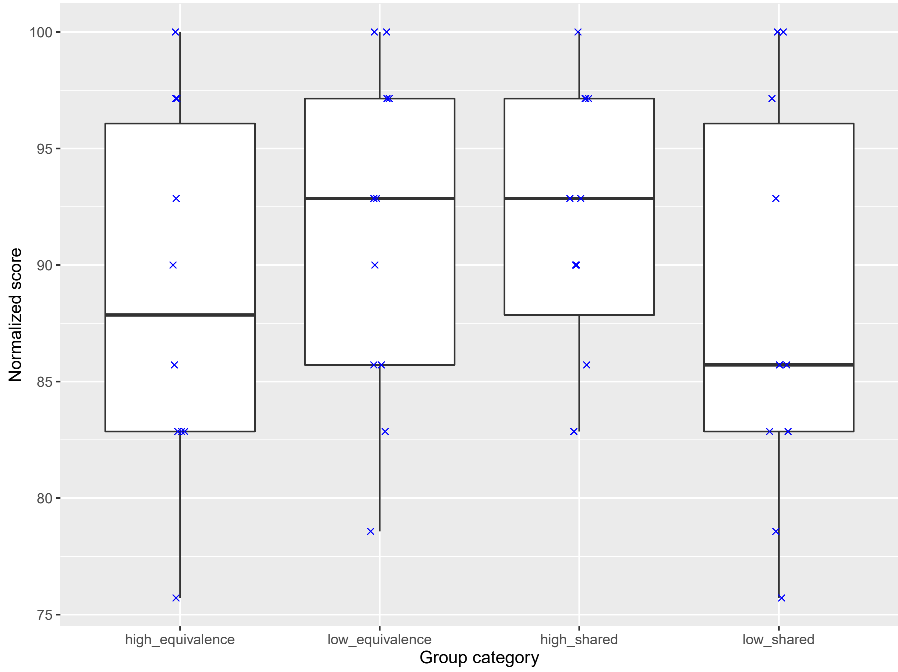

Figure 5.6: Collaborative map scores differentiated by prior-knowledge equivalence and shared knowledge about the task

RQ (a): What are the overall patterns of knowledge transfer from individual-to-group representation?

We found that both types of knowledge (shared and unshared) were highly transferred to group solutions, with a rate of 92%. In contrast, some previous studies report that groups often abandon unshared knowledge or resources (F. Fischer & Mandl, 2002; Gracia-Moreno et al., 2017). This indicates that this approach has the potential to create awareness of others' understanding regardless of the type of knowledge. The weak correlation between individual map scores and the normalized transfer of unshared-knowledge score demonstrates that students were able to detect important substructures without giving undue consideration to who was the source of information during the collaborative phase. For instance, a student who had a lower individual map score than their partner could transfer their unshared knowledge, while the one with the higher individual score might unable to convey their unshared knowledge. Another implication is that the students tended not to merely follow particular group members. They acknowledged their partners' perspectives and considered others' different understandings.

RQ (b): Does similarity of knowledge affect students' learning effectiveness in the two dimensions (i.e. interaction of individual members and group level), and, if so, to what extent?

The amount of knowledge transfer from individual to group solutions represents learning effectiveness as an interaction of individual-to-group knowledge. The results show that the amount of knowledge transfer was considerably high for all group conditions. Although there are some differences regarding the scores for knowledge transfer, for both shared and unshared knowledge, the divergence in prior knowledge or shared knowledge about the task in each group did not significantly influence the median scores for knowledge transfer (Figure 5.4 and 5.5). The distribution of transfer scores in the homogeneous

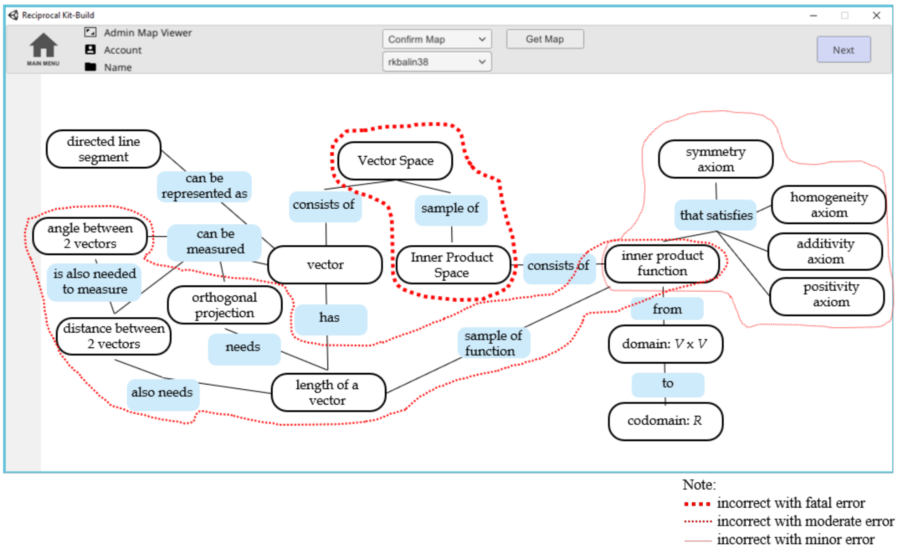

Figure 5.7: Sample of a low-quality collaborative map with the score of 75.71. Some sub-substructures were written incorrectly. The group is belong to high-prior-knowledge-equivalence and low-shared-knowledge condition

groups has more variation than in the more heterogeneous ones. This implies that the heterogeneous groups had a higher tendency to transfer individual knowledge into group solutions. It is also interesting to note that some groups, that categorized as homogeneous groups, did not transfer all of their individual shared knowledge. Further investigation of their group processes would be needed to reveal the problems for these specific groups.

The homogeneous groups, based on their prior-knowledge equivalence, demonstrated lower achievements than the heterogeneous groups (Figure 5.6). Meanwhile, the groups that were more homogeneous in terms of their shared knowledge achieved higher scores than the other groups. Despite this, the map scores for groups of different composition were not significantly different. Since the knowledge-equivalence score was based on prior knowledge, the low-equivalence groups might have broader perspectives on some previous topics that were not directly connected to the mapping task. In contrast, the shared-knowledge scores were measured from the maps themselves. Therefore, the low-shared-knowledge groups might initially attempt to resolve conflicts over certain concepts, while the high-shared-knowledge groups could focus directly on building better maps.

RQ (c): Does similarity of knowledge affect the experiences of participants in the study, and, if so, to what extent?

The affective responses of the groups demonstrate that learners in higher-shared-knowledge groups are slightly more positive than those working in low-shared-knowledge conditions. Participants under both conditions display similar patterns: they thought that our activities were stimulating and attractive, rather than perspicuous. Difficulties appeared when they faced differences in ideas or perspectives and needed to resolve those conflicts in order to reach a single group solution. Although pursuing conflict resolution is essential for conceptual change and advancement of knowledge in collaborative learning (Chan et al., 1997; Roschelle, 1992; van Boxtel et al., 2002), the learners responded negatively. This might affect their motivation for participating in collaborative activities. Further studies on how computer-based visualization can be utilized to assist learners during conflict-oriented and integration-oriented consensus building are indispensable.

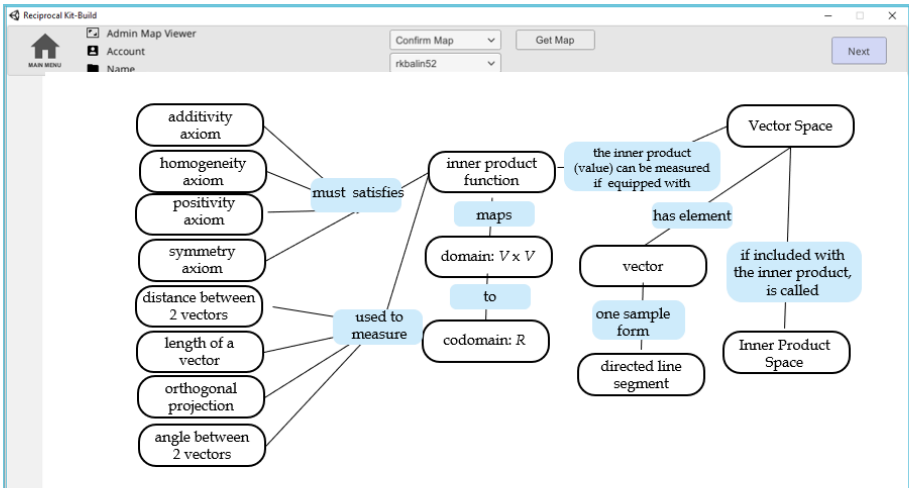

Figure 5.8: Sample of a high-quality collaborative map with the score of 100. The group is belong to low-prior-knowledge-equivalence and low-shared-knowledge condition

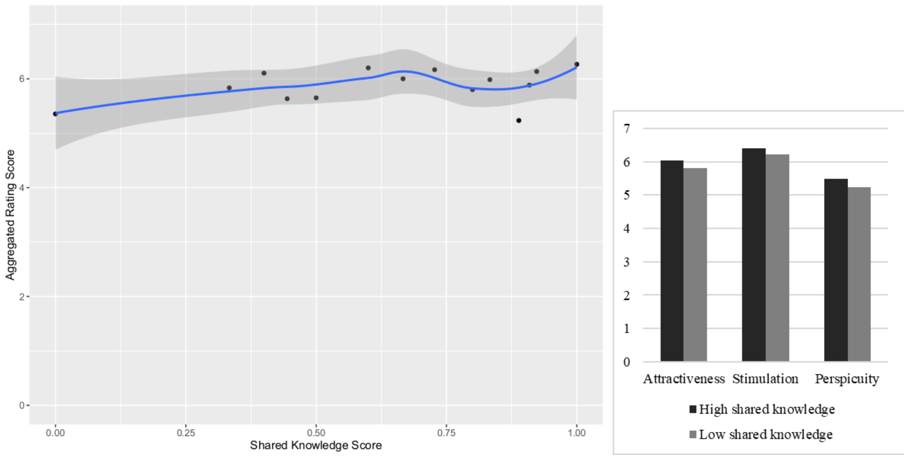

Figure 5.9: Distribution of affective responses across different shared-knowledge scores

Limitations and some potential future works

Several limitations to this preliminary study need to be acknowledged. The current study has evaluated the learning effectiveness of collaborative concept-mapping activities only in two different dimensions (i.e. the level of the group as a whole and the level of interaction between individual and group). We have not investigated their effectiveness at the level of individual learning since there is a lack of evidence related to individual performance after collaboration. A prior study suggests that the level of convergence achieved during collaborative concept mapping may influence individual performance after collaboration (Gnesdilow, Bopardikar, Sullivan, & Puntambekar, 2010). Since the amount of knowledge transfer during collaboration is significant, this approach has the potential to support learners in attaining learning effectiveness at the individual level. Furthermore, an evaluation of individual learning achievements after collaboration is necessary to get more comprehensive understanding of its effect at the individual level.

The concept mapping activity was conducted once during two hours class session. It is may insufficient to infer the generalizability of the results, more experimental session during one term of study is strongly recommended. Further studies with a large number of participants from different subject areas are also necessary to identify the breadth of this approach. It would also be interesting in the future to compare the results of groups with reciprocal teaching activity and conventional collaborative concept mapping without the reciprocal cycle since the current study is a single group design without a comparison group.

5.5 Conclusion

In summary, the current study finds that, following the designated activities, learners are informed about their partner's understanding, whether such knowledge is shared or unshared. Furthermore, they have a greater tendency to elaborate it into group knowledge. Groups with high and low similarity of knowledge achieved similar learning effectiveness at the level of interaction between individuals and group as whole. Differences in group composition, based on similarity of prior knowledge or shared knowledge about the task, does not significantly differentiate the learning effectiveness. However, since the designated activities enabled tangible expression of individual knowledge structures, the amount of joint knowledge within the group may possibly affect group outcomes. Moreover, different opinions or perspectives on the task itself influence learners' overall experiences within a collaborative environment.

These findings enhance our understanding of the effect of the RKB approach for collaborative concept mapping across different group compositions. This investigation is also useful to provide suggestions regarding group formation for the practitioners who intend to apply the approach in their classroom. It also provides future direction to advance the RKB system, for example by designing a computer-based visualization that would help students to resolve conflicts and reach a consensus. Though the students may acknowledge dissimilar perspectives from the partner's representation, integrating different ideas continues to be a challenge for them.

Chapter 6

Predicting collaborative products based on similarity of knowledge and comprehension of partner's representation

Summary

Previous studies have shown that the visualization of similarities and differences during discourse correlates with the improvement of concept map quality. This chapter presents the investigation on the effects of the first and second phases, in terms of the final group products. The correlations between the similarity of individual knowledge represented in the first-phase maps, the comprehension of a partner's representation during the second phase, and the changes of map scores are analyzed. The findings indicate that comprehension level is a stronger predictor than the similarity of individual knowledge in estimating score gain. The ways in which patterns of knowledge transfer from individuals to group maps, which exhibit how group products are built based on individual inputs, are also discussed. The evaluation also illustrates that the number of shared and unshared links in group solutions are proportionally distributed. Furthermore, the number of reconstructed links dominates the group solutions, rather than the non-reconstructed links, indicating that students prefer considering individual knowledge.

6.1 Introduction

Mutual understanding of the partner's perspectives and shared interpretations of the problem being addressed are essential requirements for collaboration. Heterogeneous group composition promotes the negotiation of perspectives towards a shared understanding. However, in a practical classroom situation, assessing similarities of prior knowledge beforehand is not always applicable. Previous studies suggest that social interaction is essential for promoting knowledge convergence; i.e., an increase in knowledge possessed by all collaborating partners after collaboration (Baines et al., 2009; Jeong & Chi, 2007; Roschelle, 1992). Some researchers have attempted to promote productive interaction by employing script, scenario, or visualization tools (F. Fischer & Mandl, 2002; van Boxtel et al., 2002).

Concept maps have been extensively used as a visualization tool to articulate complex ideas and maintain shared focus during a discussion. Studies have found that employing a concept map in collaborative learning shows significant learning gains related to the quality of student interaction during discussions (van Boxtel et al., 2000, 2002). Moreover, collaborative concept mapping activity has a positive effect on students' attitudes, specifically in increasing group motivation and students' responsibility for their own learning (Beers et al., 2006; van Boxtel et al., 2002). However, conflicting evidence has also been found, indicating that students spend a considerable amount of time focusing on task collaboration, procedure coordination, and team coordination, rather than on discussions about the concepts or relationships involved (Chiu, 2003). Others have also found that some inaccurate ideas are never challenged and can become ingrained (Roth & Roychoudhury, 1992).

A strategy to foster knowledge convergence during collaboration is by nurturing group members to apply the knowledge available to them, both shared and unshared knowledge. The RKB approach, as introduced by (Wunnasri et al., 2018a, 2018b), allows students to externalize their thinking, exchange knowledge through reconstruction, and discuss group members' similar and dissimilar areas of understanding, with the support of a difference map. The approach engages group members to operate on boundary objects; i.e., the map structures and components. Through utilizing these boundary objects, various learning mechanisms, such as coordination, reflection, and transformation of individual knowledge, are expected to occur.

Previous studies showed that the RKB approach promotes productive discussion (Wunnasri et al., 2018a, 2018b). Unlike those studies, after following the proposed activity, we ask the students to build an integrated map that represents their understanding as a group. A preliminary study on RKB for collaborative learning has explained how the approach affects collaborative learning outcomes and students' learning experiences (Sadita et al., 2018); however, it does not investigate how individual prior knowledge convergence and comprehension levels through reconstruction may potentially influence the final collaborative product. It also does not identify how knowledge is potentially transferred from individual solutions, according to the similarity of knowledge and comprehension levels between the group members. Thus, the current study aims to address those issues (Sadita, Hirashima, Hayashi, Furtado, et al., 2020; Sadita, Hirashima, Hayashi, et al., 2019). Identifying the relationship between the individual and group product is important since there is interdependence between these two. The results of this study highlight the role of individual phases of RKB activities in foreseeing students' learning achievements as a group.

6.2 Data analysis

6.2.1 Data source

Knowledge convergence is divided into knowledge equivalence and shared knowledge, which can be evaluated prior to, during, and/or after collaboration (Weinberger et al., 2007). Knowledge equivalence refers to learners in a group possessing a similar degree of knowledge related to a specified subject, regardless of the specific concepts constituting the knowledge content (Weinberger et al., 2007). While shared knowledge alludes to the knowledge of specific concepts that learners within a group have in common (Weinberger et al., 2007). This study evaluates knowledge convergence at a group level prior to collaboration, based on the definition of shared knowledge on the assigned task.

All students' individual maps (i.e., the first and second maps), and the collaborative group maps, were recorded through a web-based RKB system. The similarities and differences among group members or between individual maps and the group map were measured to determine the similarity of knowledge and potential knowledge transfer from individual inputs. The similarity of knowledge at structural and semantic levels was calculated automatically based on the map links and linking words (Qian, Sural, Gu, & Pramanik, 2004). Moreover, as an expert, the class instructor was responsible for assessing all students' individual and group maps based on the completeness and correctness of the information presented. The change of map scores was analyzed to determine group learning achievements by using a normalized change formula (Marx & Cummings, 2007).

6.2.2 Similarity of students' prior knowledge (before collaboration)

The similarity of individual prior knowledge is investigated based on the students' first maps. A concept map can be represented as a graph, hence graph similarity measures can be used to identify the similarity between map elements such as nodes and links. In this study, since all individuals' maps consist of pre-defined nodes, the similarities and differences regarding individual knowledge representation are portrayed based on the map links and their corresponding linking words.

The concept map similarity measures are adopted from the formula used by Ifenthaler (Ifenthaler, 2010), which follows the similarity definition proposed by Lin (Lin, 1998); that a similarity between objects A and B is related to their commonality and the differences between them. The maximum similarity between objects A and B is reached when A and B are identical, regardless of how much commonality they share. The similarity between A and B is measured by the ratio between the amount of information required to state the commonality of A and B and the information needed to fully describe what A and B are (Lin, 1998).

A graph $G = (V, E)$ is a finite set V of n nodes and a set E of edges, where E is a subset of $V \times V$. Given two undirected and labeled graphs, $A = (V, E_A)$ and $B = (V, E_B)$, with common node set V, $S(A, B)$ is the similarity between A and B as measured by S. SE_{AB} consists of shared links between E_A and E_B while UE_{AB} contains a set of unshared links created by only one of the group members.

$$SE_{AB} = E_A \cap E_B \tag{6.1}$$

$$UE_{AB} = E_A \ominus E_B \tag{6.2}$$

$$S(A, B) = \frac{|SE_{AB}|}{|SE_{AB}| + \frac{|UE_{AB}|}{2}} \tag{6.3}$$

The current study only considered structural similarity as in Eq.(6.3) to measure the similarity between two concept maps since it represents the whole structure of the maps as graphs. The score is defined on a scale between 0 (no structural similarity between two maps) and 1 (absolute similarity between two maps).

Further investigation on the similarity of a pair's linking words is also carried out to discover semantic similarity between two individual maps. However, this measurement only covers common map elements that were defined by the students, such as the shared links. The similarity of linking words is calculated by employing the Term Frequency-Inverse Document Frequency (TF-IDF) cosine similarity formula (Qian et al., 2004) for each shared link on the first maps. This approach is widely used to establish the similarity between two texts. It can be categorized as a lexical similarity approach based on character and statement matching. To enhance the quality of measurement, some text pre-processing techniques are applied, such as text normalization (e.g., transforming to lower case, removing punctuation, stemming) and stop-word removal. Using the TF-IDF cosine similarity formula, the similarity score is between 0 and 1. In addition, linking-word similarity falls into three following categories: **no similarity** if the score is 0; **moderately low similarity** if the score lies between 0–.509; and **moderately high similarity** if greater than .509. This categorization is based on the first and third quartiles of the similarity score distribution ($M = .27, SD = .34, Q1 = 0, Q3 = .509$). The first quartile ($Q1$) is the middle number between the smallest number and the median of the data set, while the third quartile ($Q3$) is defined as the middle number between the median and the highest number of the data set.

6.2.3 Comprehension of the partner's map components

Comprehension of the components of the partner's map represents how effectively an individual can express their understanding of their partner's map components (nodes and links), in the form of a concept map. Since the list of concepts is defined by the teacher, the measurement only considers the reconstructed partner's links.

A graph $G_A = (V, E_A)$ is a finite set V of n nodes and a set E of edges built by student A. A graph $R_A = (V, E_{RA})$ is a graph re-constructed by student A's partner. Let E_{MA} be the set of A's first map links that are connected to the same nodes by the partner in the second map, while E_{NA} consists of the links that are joined to different nodes.

$$E_{MA} = E_{RA} \cap E_A \tag{6.4}$$

$$E_{NA} = E_{RA} \ominus E_A \tag{6.5}$$

The element of E_{MA} is called a reconstructed link, while E_{NA} consists of non-reconstructed links. Given two undirected and labeled re-constructional graphs R_A and R_B with common node set V, $C(A, B)$ is the comprehension value between student A and B, as a pair in a group, defined as:

$$C(A, B) = \frac{|E_{MA} + E_{MB}|}{|E_{MA} + E_{MB}| + \frac{|E_{NA} + E_{NB}|}{2}} \tag{6.6}$$

6.2.4 Transfer of elements from individual to group maps

The transition (or change) of elements from the first maps to the second maps and the group maps provides a deeper understanding of how the individuals build on each other's ideas to construct a collaborative product. The transfer of elements is indicative of an individual's input in the group solution. The number of concepts in the group solution that exist in at least one of the group member's individual maps is used in(Stoyanova & Kommers, 2002) to measure individual-to-group transfer.

In the current study, link connections and linking words are considered as elements for measuring transfers. The number of individual map links, both shared and unshared, accepted as components for the group map describes the transfer of link elements. From those transferred links, the corresponding linking words in the individual and group maps are extracted to measure semantic similarity. By applying the TF-IDF cosine similarity formula (Qian et al., 2004)) and some pre-processing techniques, the similarity score is calculated. The similarity value is from 0 to 1 inclusive, with the mean of .68 and standard deviation of .37. Furthermore, the first and third quartiles of the data distribution are used to define thresholds for categorization ($Q1 = .366, Q3 = 1$). The categories of individual-to-group linking word similarity are as follows:

- **follow initial**: the group of linking words that are similar with at least one of the individual linking words (similarity value of equal to or more than .99);
- **modify initial**: the group of linking words that are modified from one of the individual linking words (similarity value above .366 and below .99);

Table 6.1: Descriptive statistics

Data	***M***	***SD***	***Min***	***Max***
$S(A,B)$	.47	.27	0	.93
$C(A,B)$	.85	.12	.65	1
ais	72.21	18.22	41.43	98.57
gms	90	7.31	75.71	100
c	.54	.34	-.09	1

- **new**: the group of linking words that are not similar to any of the individual linking words (similarity value of below .366).

6.2.5 Group learning achievements: map score change

To measure the change of map score from the individual to the collaborative phase, this study adopts the normalized change formula proposed by Marx and Cummings (Marx & Cummings, 2007). The procedure involves the ratio of the gain to the maximum possible gain, or the loss to the maximum possible loss. If the gain is zero, the normalized change $c = 0$, except when a student earns a zero or a perfect score on the pre-test and post-test. Since this study aims to investigate the learning outcomes at the group level, the average of individuals' first map score is defined as the pre-score, while the final collaborative map score is regarded as the post-score. Let ais represent the average of individual (first) map score, and gms represent the final collaborative map score for each group. The normalized score gain (c) is defined as follows.

$$c = \begin{cases} \frac{gms-ais}{100-ais} & \text{if } gms > ais \\ \text{drop} & \text{if } gms = ais = 100 \text{ or } 0 \\ 0 & \text{if } gms = ais \\ \frac{gms-ais}{ais} & \text{if } gms < ais \end{cases} \tag{6.7}$$

6.3 Results

6.3.1 Relationship between group prior knowledge similarity, comprehension of the partner's kit, and map score change

Table 6.1 summarizes the descriptive statistics of the similarity ($S(A,B)$), comprehension level ($C(A,B)$), and the average individual score (ais), group map score (gms), and normalized change (c). From the 22 groups of participants, one group should be omitted from the analysis because they achieved perfect scores on both the ais and gms. A paired-samples t-test is conducted to compare the group average individual score and the group map score. There is a significant difference between the average individual score ($M = 72.21$, $SD = 18.22$) and the group map score ($M = 90$, $SD = 7.31$); $t(20) = 4.92$, $p < .01$. These results show that in general, the collaborative outcomes increased. Eighteen groups showed better group map outcomes, two groups retained the same scores, and one group received a lower score. The detail of changes of map qualities from individual maps to group map is presented in (Sadita et al., 2018).

Figure 6.1 depicts the distribution of the group's prior knowledge similarity (Eq. 6.3) and normalized score gain from individual to group map (Eq. 6.7). Two groups have the same similarity value and normalized gain, ($S(A,B) = .93, c = 0$). This duplicate score

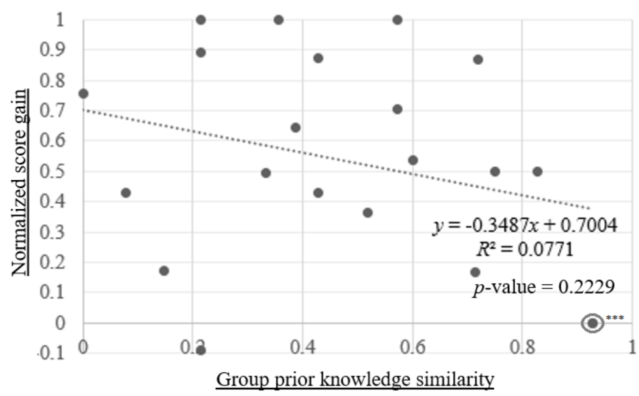

Figure 6.1: Scatter plot of group prior knowledge similarity and normalized gain from individual to collaborative map

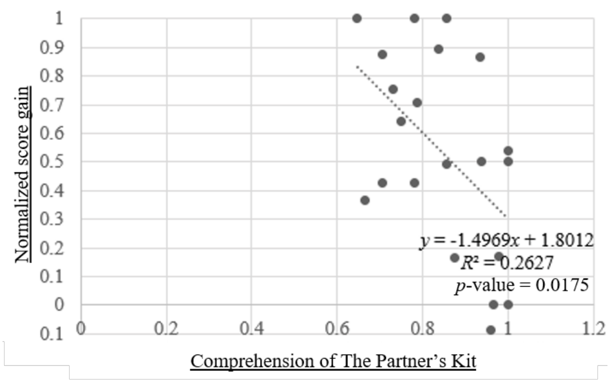

Figure 6.2: Scatter plot of group comprehension level and normalized gain from individual to collaborative map

is marked with a double circle and asterisk symbol (***) in Figure 6.1. Based on the structural similarity of the first individual maps, there are 6 groups with similarity values of equal to or more than .714, 9 groups with similarity values between .214 and .714, and the other 6 groups have lower similarity values. The variable group prior knowledge similarity and normalized score gain are found to be weakly negatively correlated, $R(19) = -.278$, $p = .22$.

Figure 6.2 shows correlation between the comprehension level of the partner's representation (Eq. 6.6) and normalized score gain (Eq. 6.7). The comprehension of the partner's presentation and normalized score gain are moderately negatively correlated, $R(19) = -.51$, p ¡ .05. As comprehension increases, normalized change decreases. Though the similarity of prior knowledge and comprehension of the partner's map elements show a moderately positive correlation with significant coefficient, $R(19) = .47$, p ¡ .05, comprehension level is a stronger predictor than level of similarity of prior knowledge for normalized score gain. Both Figure 6.1 and 6.2 depict the new results presented by the current study.

In total, over 445 unique links are written by the students in their first maps (see Figure 6.3). Thirty-one percent of those links belong to shared links ($n = 140$), while the remaining links are unshared ($n = 305$). Almost all shared links can be reconstructed (99%, $n = 138$). Some unshared links can also be reconstructed (62%, $n = 190$). The number of unshared links which can be reconstructed is higher than that for non-reconstructed links ($n = 115$).

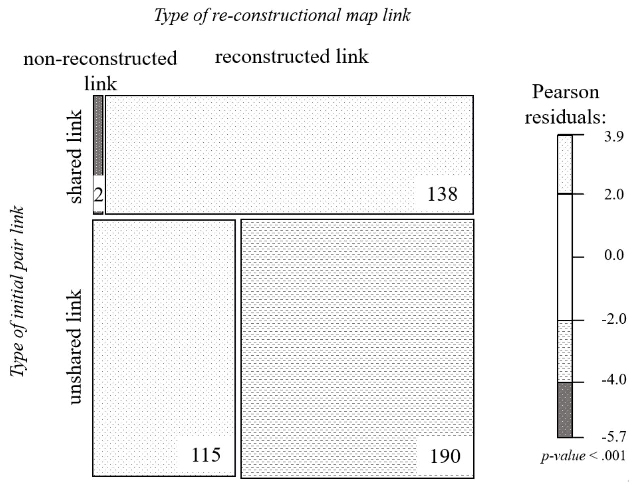

Figure 6.3: Mosaic plot of similarity of prior knowledge and comprehension of partner's kit

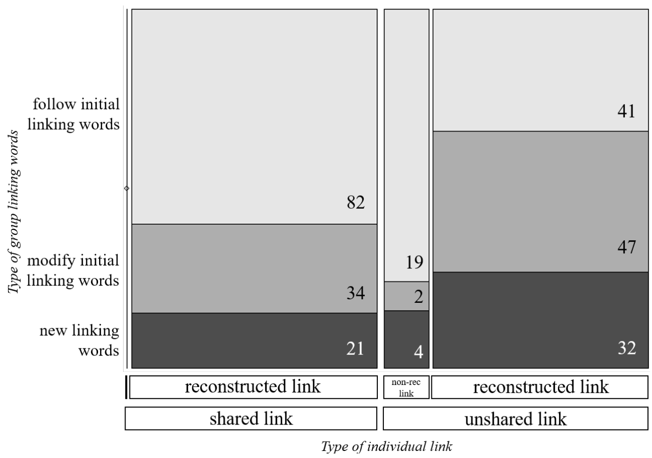

Figure 6.4: Source of group map components

6.3.2 Individual contributions to collaborative products

In this subsection, the similarity levels between the actual collaborative product and each group member's individual map are compared. Figure 6.4 depicts the distribution of shared, unshared, reconstructed, and non-reconstructed links across all group maps. The total number of group links generated by the 21 groups of students is 307, of which 92% (n = 282) resembles the first map's links. Both shared and unshared links contributed proportionally to the group map (n = 137 and n = 145, respectively). The number of shared and unshared links is different from the one in section 4.1 because not all individual links were composed in the group maps. The reconstructed shared and unshared links were more likely to be accepted than the group links. None of the non-reconstructed shared links are represented among the group links, and few of the non-reconstructed unshared links are available in the group maps (17%, n = 25 out of 145). Further, about 8% of the group links are newly generated links. Since most of the group links are similar to the initial links in the students' first maps, the similarity levels between the linking words of the initial and the group links are measured. The distribution of linking-word similarity among different types of links is also presented in Figure 6.4.

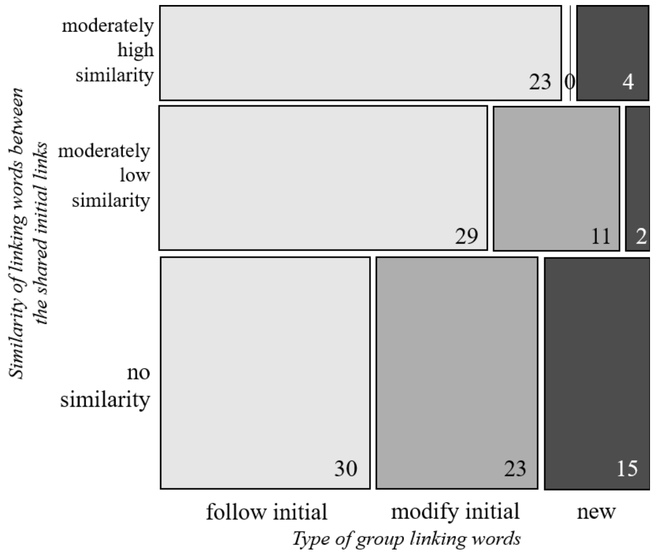

Figure 6.5: Transfer of individual linking words to group map

Moreover, Figure 6.5 shows how the students employed linking words from the initially shared links to compose group propositions. When the similarity of initial linking words is moderately high, the tendency is to use any group member's initial linking words without modifications. In cases when the similarity is moderately low, any of the group member's linking words could be chosen (69%, $n = 29$). However, the tendency is to modify or create new linking words (56%, $n = 38$) when there is no similarity.

6.4 Discussion

The results indicate that there is an improvement in the generated map based on expert judgement and normalized change measurement ($M = .54$, $SD = .34$), as shown in Table 6.1. Further, Pearson's correlation analysis shows that comprehension level and normalized change of products from individual to group level shows a moderately negative correlation, with a significant coefficient, while similarity of prior knowledge reveals a weaker correlation with normalized change. The results show that the comprehension of the partner's representation is a stronger predictor to detect the normalized change when compared to the similarity of prior knowledge.

The similarity between the individual and group maps represents individual input to the group outcome. Providing a set of disconnected partner's map components prompted students to reflect their understanding of their partner's representation. A Wilcoxon signed-rank test indicates that the median of the similarity score between students' second maps and their partners' first maps ($Mdn = .746$) is significantly higher than the median of the similarity score between students' second and first maps ($Mdn = .6), Z = 224.5, p < 0.01$. This illustrates that, when students reconstructed their partners' components, they were making an effort to understand their partners' maps, rather than to express their own initial maps by using new components. In this context, the map components function as boundary objects that can be operated to identify similarities or differences in perspectives, and as mediating artifacts during coordination. Furthermore, boundary-crossing activities may lead to changes in practice (transformation of knowledge) (Akkerman, 2011).

Surprisingly, the results also show that the numbers of shared and unshared links in the group solutions are proportionally distributed. While constructing a group map, the students were tempted to manipulate their first map components rather than creating new

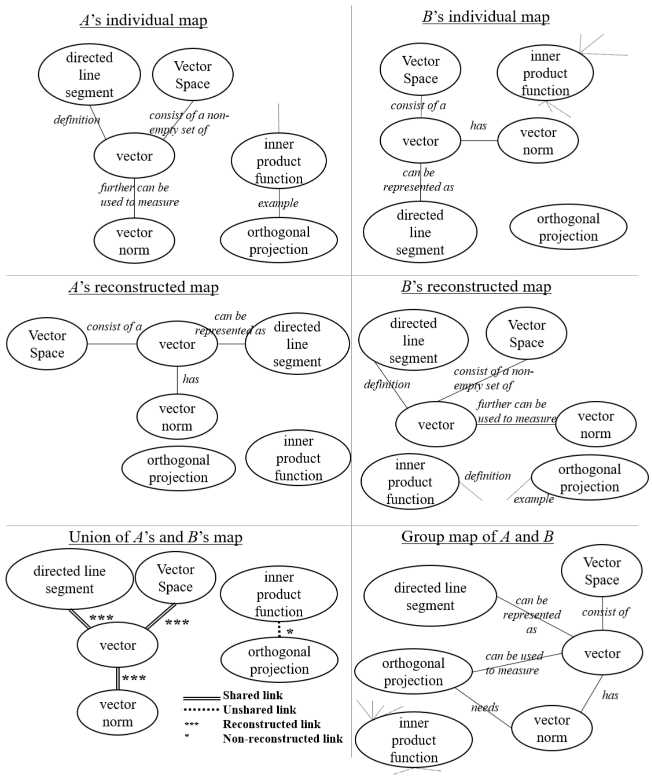

Figure 6.6: Sample of individual maps of two students in a group, their reconstructed maps, the corresponding union map with the categorization of links, and the newly transformed group map

links. This is an indication that the students were reflecting on their individual available knowledge to construct the group product. The results also demonstrate a considerable number of reconstructed unshared links in the group map, which could indicate that the students were able to accept reconstructed elements as parts of group solutions, although they involved different representations. Many initial linking words with zero similarity scores from the shared links were modified, which reveals that the students attempted to resolve conflicts regarding different link definitions. In contrast, the individual linking words with higher similarity scores were more likely to be included in the group map without any modification. Figure 6.6 shows an example of the transformation from individuals to group following the unshared or non-reconstructed links; i.e., related to the node of orthogonal projection. In the group map that link connection differs from any existing individual map components. The incorrect knowledge on the individual maps was finally corrected through the collaborative activity.

Allowing students to review all members' first maps, as a form of access to distributed cognitive resources, should positively affect the broadness of group problem solutions (Stoyanova & Kommers, 2002). To support the creation and evolution of active boundary objects, Fischer suggests providing systems that can create awareness of each other's work among group members, afford opportunities for individual reflection and exploration, enable co-creation, allow participants to build on the work of others, and provide mechanisms to help draw out tacit knowledge and perspectives (G. Fischer, Giaccardi, Eden, Sugimoto, & Ye, 2005). Reconstruction and discussion supported with the difference map during the RKB activities trigger reflection and exploration activity, enabling group members to review each other's representation. Also, such an approach may potentially foster knowledge convergence after collaboration; that is, the similarity of knowledge possessed by group members after collaborative learning (Weinberger et al., 2007). Interdependence exists between the effectiveness of group and individual learning, and more successful groups are more beneficial to their members as individuals (Stoyanova & Kommers, 2002).

Limitations and some potential future works

The current study's results have been derived based on the group learning outcomes; however, further investigation of the effect at the individual level is important. This study excluded consideration of the effectiveness at the level of the individual since we did not collect individual post-collaboration maps, due to time limitations enforced by conducting the experiment in a practical classroom. The similarity between the group and individual post-collaboration maps represents the knowledge that is transferred from the shared group cognition to individual cognition, and is indicative of individual learning outputs (Stoyanova & Kommers, 2002).

The findings of this study have some important implications for future practice. This study suggests developing a feedback system based on the similarity of prior knowledge and the comprehension of the partner's representation. The system could provide a recommendation for the teacher to form a group in consideration of the similarity of initial maps. Moreover, the teacher may utilize the results of reconstruction to predict the group outcomes. If necessary, specific treatment should be provided to assist learners who face difficulties to progress. In addition, the system may display an integrated difference map to support learners in accommodating different representations while composing a group map. The integrated map could show the reconstructed and non-reconstructed elements. A recommendation to select or modify the initial linking words could be useful to enhance the final results and reduce the time necessary to construct a group map. Combining different perspectives is a challenging task for the students. If this process is supported, the number of transfers from group to individual cognition would be potentially increasing. Hence, fostering knowledge convergence after collaboration.

Supporting function for collaboration

Possible suggestions provided by the KB system (Figure 6.7) are as follows:

- **Nodes**: When constructing a map, one would usually start from the root nodes. To determine the root, the KB system calculates the centrality of each node based on the number of links connected to it. The most connected nodes will be placed in the center, surrounded by clustered relevant nodes.

- **Links**: By integrating two shared maps, the system will be able to detect the most desirable links from the matching ones, as a group tend to retain these links in their final group map (Sadita, Furtado, et al., 2020; Sadita, Hirashima, Hayashi, Wunnasri, et al., 2020). Following the excessive or lacking links in the difference maps, students may intend to choose either an excessive or a lacking link (Sadita, Hirashima, Hayashi, Wunnasri, et al., 2020). The number of excessive links has a moderate, positive correlation with the change in quality of the group map; therefore, we display those links as suggestions in a separate layer.

- **Linking words**: The linking words from the difference maps will be shown to allow students to build upon the work of all group members. They may also define new linking words, if necessary. Students can add or modify concepts, links, and linking words to enhance their group products with new ideas, after consensus building. They may also adjust the map layout, accordingly.

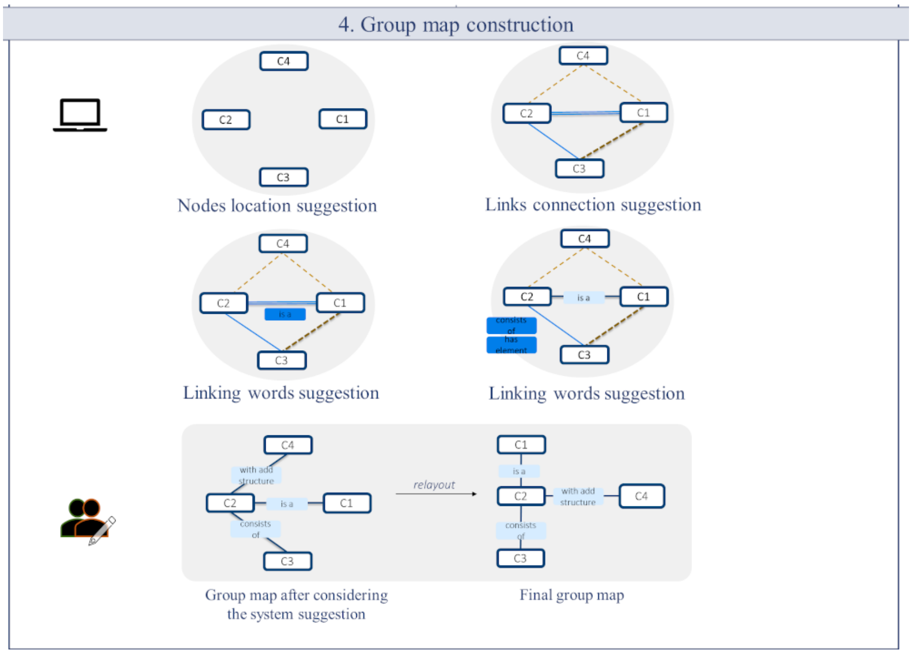

Figure 6.7: Samples of Kit Build suggestion to aid group map construction

The design activity enables learners to externalize their individual ideas, to review a learning partner's map through partner-map reconstruction, and discussion of the difference map, before commencing co-construction of the concept map. Maldonado, Kay, and Yacef (2012) designed a similar tabletop CCM activity to the one in this current study that allowed learners to draw a concept map in an individual space, as well as a group space. After working individually on a desktop computer, the learners would actively co-construct a concept map on a tabletop. The tabletop system provided node and link suggestions based on the integration of individual suppositions. It also highlighted similarities and differences of individual maps on separate layers. However, unlike their design, this study considers the results of reconstruction to be included in the collaborative map, as depicted in (Figure 6.7).

6.5 Conclusion

The present study conducted an investigation on how the similarity of individual prior knowledge and the comprehension of partner's representation during the RKB activities may influence the students' final collaborative outcome. The results of this investigation show that the comprehension of partner's representation in the form of reconstruction is a stronger predictor for estimating score gain, rather than the similarity of prior knowledge. Reconstruction triggers learners' interaction by providing the boundaries for students to operate on their initial knowledge. Similarities in prior knowledge may influence the broadness of group solutions. In addition, the evaluation of partner comprehension through reconstruction has potential for encouraging further modification of individual knowledge.

One of the more significant findings to emerge from this study is that students work on their individual ideas during the collaborative phase. They utilize their initial shared and unshared knowledge when building collaborative products. A considerable number of reconstructed links dominate the final group maps, despite the similarity of links. Different linking words are more likely to be modified, while the highly similar ones are easily accepted as it is. Active reviewing on individual ideas has the potential to foster knowledge convergence after collaboration. However, the current study has not addressed it yet. A future study investigating the analysis of knowledge similarity after collaboration is needed to reveal the effect of the RKB approach at the individual learning achievements. Another limitation of this study is that the number of participants and course subjects were relatively small. Further research needs to be done with more participants and various course topics.

Chapter 7

Conclusion

7.1 Summary of findings

The main results show that following the RKB activities:

1. The students build high-quality group products. The students build high-quality group products. The sequence of CCM activities with the RKB approach supports learners to achieve high-quality collaborative products, as in previous CCM studies, with individual externalization and knowledge awareness tools.

2. The students perceived positive responses towards the activities. The students also positively accepted the learning activities. Positive student attitudes towards the activities signify the usefulness and attractiveness of the RKB approach.

3. Group formation based on the similarity of individual knowledge does not significantly affect the individual-to-group transfer of knowledge and the group outcomes; however, it may prompt students to experience different perspectives toward the activities.

4. The comprehension of a partner's representation is a stronger predictor in estimating the group outcomes, compared to the similarity of initial knowledge. Groups who experience a lower comprehension value earn a better score during CCM , indicating that students were attempting to change their initial knowledge. Similarities in prior knowledge could influence the broadness of group solutions. Furthermore, the evaluation of partner comprehension through reconstruction has potential for encouraging further modification of individual knowledge. The KB visualization of map differences can act as a guide to modify existing knowledge, which is reflected in the patterns of modifications from the individual to the group maps.

7.2 Limitations of the study and directions for future studies

Several limitations to this preliminary study need to be acknowledged.

- Generalizability of findings:
  The concept mapping activity was conducted once during a two-hour class session, which is insufficient to infer the generalizability of the results. Although a thorough analysis of the generated maps and perceptions of the students has been conducted, subsequent experimental sessions over the duration of a term of study is strongly recommended. Further studies with a greater number of participants across a variety of subject areas is necessary to identify the breadth of this approach.

- Single group design:
  A single group study was conducted to ensure fairness in a real classroom context. In future studies, it would also be interesting to compare the results of groups with reciprocal teaching activities and conventional CCM without the reciprocal cycle. A within-subjects study, with counterbalancing and group randomization, might be a potential alternative for further research in a practical classroom setting.

- The evaluation of learning effectiveness at a group and interaction level:
  The current study evaluated the learning effectiveness of CCM activities in only two dimensions (the level of the group as a whole and the level of interaction between individual and group). Consideration of the effectiveness at the level of the individual was excluded, as no individual post-collaboration maps were collected, due to time limitations incurred by conducting the experiment in a practical classroom. An assessment of the effect of learning on an individual level is necessary to fully comprehend the current findings. In future studies, students should be requested to build post-collaboration maps or complete a pre- and post-test as part of the experimental activities. The similarity between the group and individual post-collaboration maps represents the knowledge that is transferred from the shared group cognition to individual cognition and is indicative of individual learning outputs (Stoyanova & Kommers, 2002).

Aside from the limitations of this study, its findings have other implications for future practice:

- Development of a supporting function for collaboration:
  Based on the survey of students' perceptions towards the activities, we found that most students considered the approach as attractive and stimulating. However, the lowest items were related to perspicuity, which indicates that the students' cognitive loads were rather high. According to the open-ended survey, combining different perspectives remains a challenging task. Therefore, the development of a feedback system, based on the similarity of prior knowledge and the comprehension of a partner's representation, is suggested. An integrated difference map is a potential way to support learners in accommodating different representations while composing a group map. Furthermore, from the perspective of the class teacher, the system could provide a recommendation to form a group in consideration of the similarity of initial maps. The teacher might also utilize the results of reconstruction to predict the group outcomes. If necessary, specific treatment should be provided to assist learners who face difficulties progressing. An additional suggestion would be to divide the individual and collaborative phase across different sessions to reduce the cognitive loads on the participants.

- Bigger group size:
  The current study was administered for a pair. The issue of how to transfer this approach to more than two people would also be an interesting topic for further research.

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Appendices

A Students' experiences questionnaire

Name:
Student ID:
Phone number with Gojek account:

Questionnaire

Kit Build Concept Map

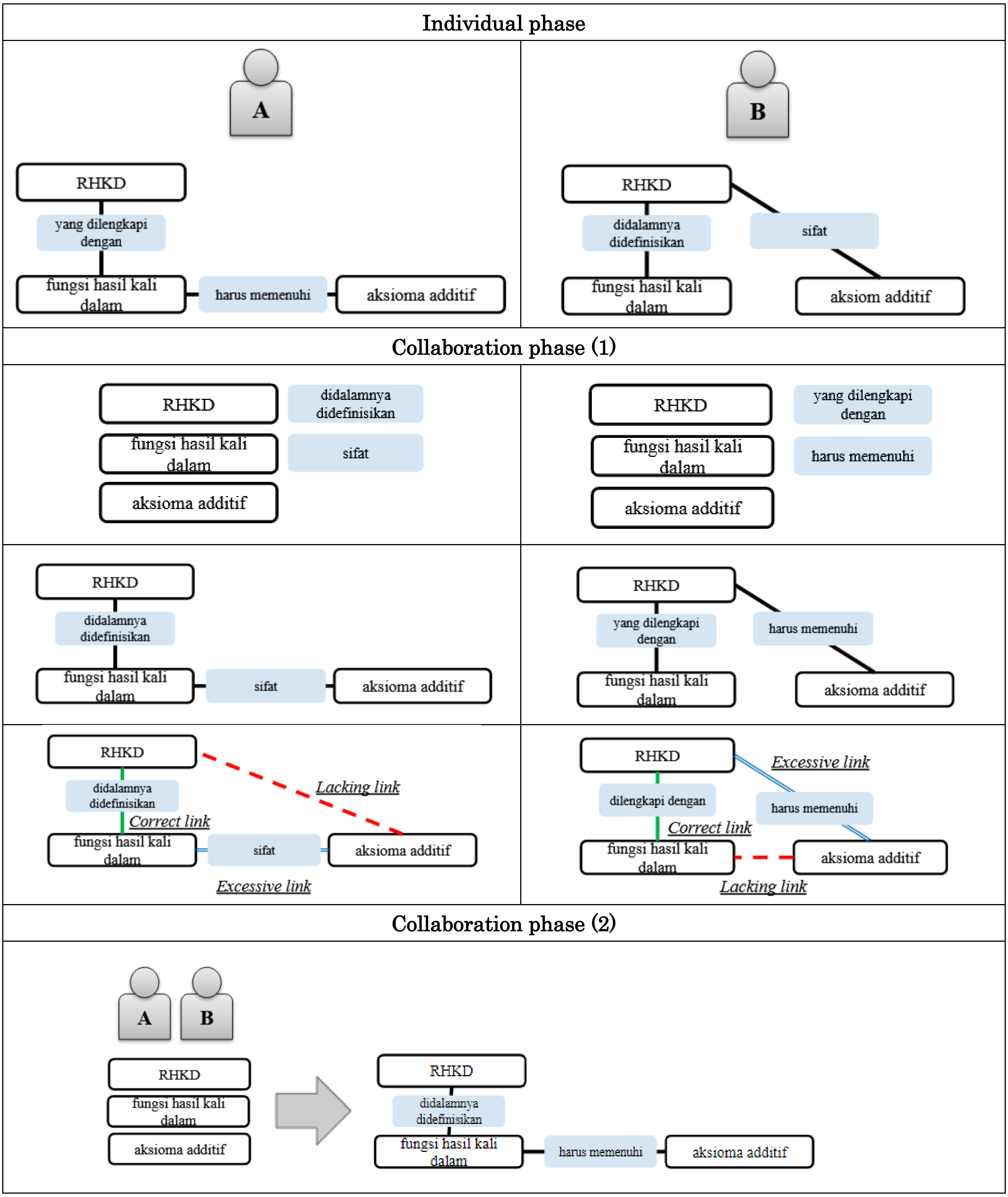
You are required to assess the use of Kit Build for creating a concept map.

Part A. You are asked to rate by inserting a cross mark on the appropriate circle.
Example:

	1	2	3	4	5	6	7	
troublesome	○	○	○	⊗	○	○	○	fun

Your opinion is critical. Please note that there is no correct or false answer.

Recalling: An Example of The Use of Kit Build Concept Map (KB)



1. KB for expressing ideas/understanding on learning materials

	1	2	3	4	5	6	7	
annoying	○	○	○	○	○	○	○	enjoyable
inferior	○	○	○	○	○	○	○	valuable
complicated	○	○	○	○	○	○	○	easy

2. KB for information elicitation from the group partner

	1	2	3	4	5	6	7	
annoying	○	○	○	○	○	○	○	enjoyable
inferior	○	○	○	○	○	○	○	valuable
complicated	○	○	○	○	○	○	○	easy

3. KB for understanding ideas of the partner

	1	2	3	4	5	6	7	
annoying	○	○	○	○	○	○	○	enjoyable
inferior	○	○	○	○	○	○	○	valuable
complicated	○	○	○	○	○	○	○	easy

4. KB for discussion with the support of visualization (figure) of the concept map differences

	1	2	3	4	5	6	7	
annoying	○	○	○	○	○	○	○	enjoyable
inferior	○	○	○	○	○	○	○	valuable
complicated	○	○	○	○	○	○	○	easy

5. KB for integrating ideas in a group

	1	2	3	4	5	6	7	
annoying	○	○	○	○	○	○	○	enjoyable
inferior	○	○	○	○	○	○	○	valuable
complicated	○	○	○	○	○	○	○	easy

Part B: Please answer the following questions in the box provided

The process of expressing ideas in the form of a concept map

6. Mention (if any) any technical and non-technical difficulty encountered while you were using Kit Build to express ideas in the form of a concept map?

The process of exchanging nodes and links with a partner

7. Mention the most interesting moments encountered while you were asked to create a concept map from your friend nodes and links.

8. Mention (if any) any obstacle encountered when you were asked to create a concept map from your friend nodes and links

Diagram (visualization) of difference map and group discussion

9. What are the most memorable moments when learning from your friend different concepts map visualized by Kit Build?

10. Mention (if any) any obstacle encountered when you were discussing with the help of visualization of Kit Build difference concept map Build Kit?

The process of constructing a group concept map

11. Mention (if any) any technical and non-technical difficulty encountered while using Kit Build to create a concept map together with your friend?

I hereby consent the use of this data to improve learning and teaching process.

Signature,

____

B Consent form

Consent to Participate in a Research Study

Title of Study: **The use of Reciprocal Kit-Build for Collaborative Concept Mapping Activities**

Investigators :

Name: **Lia Sadita** **Dept:** Information Engineering **Phone:** (+62) 812 8925 5745

Introduction

- You are being asked to be in an initial research study of Reciprocal Kit-Build for collaborative knowledge construction.
- You were selected as a possible participant because you are currently enrolled in a Linear Algebra class of 2017/2018 (even term).
- We ask that you read this form and ask any questions that you may have before agreeing to be in the study.

Purpose of Study

- The purpose of the study is to investigate the potential use of Reciprocal Kit Build as concept mapping tool during collaborative knowledge construction.
- Ultimately, this research may be published as a part of journal or presented as a paper.

Description of the Study Procedures

- If you agree to be in this study, you will be asked to do the following things:
  - create a concept map with Kit Build individually or collaboratively,
  - discuss the map with your peers, and
  - fill-out some questionnaires or being interviewed (optional).

Risks/Discomforts of Being in this Study

- There are no reasonable foreseeable (or expected) risks. There may be unknown risks.

Benefits of Being in the Study

- The benefits of participation are to practice your critical thinking skills and structured thinking, therefore, you will gain a deeper understanding on knowledge related to the learning topics.

Confidentiality

- The records of this study will be kept strictly confidential. Research records will be kept in a locked file, and all electronic information will be coded and secured using a password protected file. We will make an audio and video recording during this experiment and only the investigators or the teachers who will have access to them. All the records will be used only for educational purposes. We will not include any information in any report we may publish that would make it possible to identify you.

Incentives

- The individual and group concept map will be graded and considered as an additional score for your mid-term exam with the maximum weight of 15 pts.
- There will be no payment/reimbursement for your participation.

Right to Refuse or Withdraw

- The decision to participate in this study is entirely up to you. You may refuse to take part in the study *at any time* without affecting your relationship with the investigators of this study. Your decision will not result in any loss or benefits to which you are otherwise entitled. You have the right not to answer any single question, as well as to withdraw completely from the interview at any point during the process; additionally, you have the right to request that the interviewer not use any of your interview material.

Right to Ask Questions and Report Concerns

- You have the right to ask questions about this research study and to have those questions answered by me before, during or after the research. If you have any further questions about the study, at any time feel free to contact me, Lia Sadita at lia@lel.hiroshima-u.ac.jp or by telephone at (+62) 812 8925 5745. If you like, a summary of the results of the study will be sent to you.

Consent

- Your signature below indicates that you have decided to volunteer as a research participant for this study, and that you have read and understood the information provided above. You will be given a signed and dated copy of this form to keep, along with any other printed materials deemed necessary by the study investigators.

Subject's Name (print): ______________________________

Subject's Signature: ______________________________ Date: __________________

Investigator's Signature: ______________________________ Date: __________________