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A Preliminary Study on Knowledge Reconstruction Activity for Fostering Cognitive Presence in Online Discussion

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Abstract: Asynchronous online discussion activity has become a popular form of online collaborative learning (OCL) and has been widely adopted in higher education. In the discussion, learners are expected to effectively co-construct knowledge together through engaging in problem solving discourse. Such an ability to construct and confirm understanding while working together to solve a problem is defined as cognitive presence, which plays a central role in the success of OCL. However, despite various facilitation strategies suggested in prior studies, it is challenging to ensure that learners show sufficient cognitive presence. Providing a preparatory activity that increases engagement with learning materials before participating in the discussion is another strategy that could foster cognitive presence. This study aims to investigate the effectiveness of providing two kinds of knowledge reconstruction activities, namely kit-build concept mapping (KBCM) and summary writing, as a discussion preparatory activity. The results show that using KBCM for reconstructing basic knowledge related to discussion topic has a potential to be better for fostering cognitive presence compared to summary writing. The KBCM activity provides opportunities to engage more with basic knowledge related to the discussion topic, to confirm understanding, and to familiarize themselves with common terms or keywords used in the discussion through reconstructing a teacher-created map. Some directions for future studies are discussed.

Keywords: Mathematics education, concept mapping, online discussion, community of inquiry

1. Introduction

The emergence of various online learning technologies has paved the way for the popularity of online collaborative learning (OCL) in higher education. As an alternative to the traditional classroom, collaborative learning has been extensively discussed and promoted in several studies (Laal et al., 2012). In OCL, learners construct knowledge through online collaborative work in which they explore, invent, and apply ways to solve problems through active discourse, usually through an online asynchronous discussion forum (Bates, 2022; Harasim, 2017).

Conducting effective OCL requires an effective framework that guides the design of the activity. Effective OCL is characterized by learners' active participation in OCL processes, such as generating and organizing ideas to achieve consensus about what the problems are, how to solve them, and the solutions (Harasim, 2017). Learners' active participation is important in OCL due to its influence on learning performance (Ng et al., 2022). As a result, learners' inactivity may hinder the effectiveness of OCL (Hew et al., 2010; Mazzolini & Maddison, 2003). Unfortunately, learners' inactivity in online discussion forums has been widely reported in many studies (Fung, 2004).

To avoid or minimize inactivity and realize a successful OCL, a framework that addresses the issue of facilitation or provides facilitation strategies could be implemented. One of the OCL frameworks that addresses this issue and has been widely adopted in online learning is the Community of Inquiry (CoI) framework (Valverde-Berrocoso et al., 2020). This framework defines three elements of an asynchronous text-based OCL that make up learners' educational experience: Social presence, cognitive presence, and teaching presence (Garrison et al., 2001). These presences are the abilities that are exhibited by the participants during the collaborative activity. Social presence is related to social interaction that creates a sense of community among group members. Teaching presence is related to the design and facilitation of the activity. On the other hand, cognitive presence is related to the ability to engage and progress through inquiry steps to solve problems, i.e., to explore, integrate, challenge, and defend ideas.

A successful CoI-based discussion is characterized by the active participation of learners in sustained knowledge sharing and building activities, i.e., the existence of a series of agreements or disagreements, a high amount of information sharing related to problems, etc. This is characterized by the existence of social and teaching presences as well as a high level of cognitive presence, because serial monologues with low participation in sharing and challenging ideas are not enough for deeper learning (Garrison & Cleveland-Innes, 2005). However, realizing a successful CoI-based discussion is challenging, especially fostering a high level of cognitive presence. There is a possibility that learners are not actively participating in the discourse or producing a low-quality discussion. Simply creating discussion tasks is not enough to encourage idea integration and the discovery of novel insights (Moore & Miller, 2022).

Providing a training as a preparatory activity, which could make the learners aware of what kind of activities they could do to facilitate the discussion and understand the importance of having a sense of belonging as a group before the inquiry process begins, could foster teaching presence and social presence (Junus et al., 2017). Nevertheless, in some cases, providing training alone is insufficient for fostering high cognitive presence. Such training is predicated upon the assumption that participants are expected to provide effective direct instructions to sustain the inquiry process. A recent study showed that the effectiveness of some forms of facilitation to improve cognitive presence is still inconclusive (Moore & Miller, 2022).

Moreover, fostering cognitive presence is more challenging because providing training alone as a preparatory activity is insufficient. In addition, the forum itself, as a mere learning environment, does not automatically foster a high level of cognitive presence (Moore et al., 2019; Sadaf & Olesova, 2017). Based on this issue, there is a need to foster cognitive presence for successful CoI-based discussion by improving the preparatory activity.

A prior study suggested that providing individual preparatory activities could improve discussion quality, which is characterized by a higher ability to express and elaborate ideas (Sadita et al., 2020). One possible alternative for improving the preparatory activity is providing certain activities or technologies into the process to make learners more engaged with learning contents (i.e., basic knowledge required for understanding the problem given in the discussion (Saadatmand et al., 2017). An activity in which learners organize information related to the basic knowledge of the discussion topic could be offered as a preparatory activity. Such activity is intended to familiarize the learners with concepts and terms used in the discussion and give them a "bigger picture" of what they are going to discuss through reviewing related learning materials.

Summary writing is one of the strategies to increase engagement with the learning contents related to discussion topic from knowledge generation through reviewing and expressing concepts using learners' own word (Richards et al., 2023). The other alternative is concept mapping, which could increase engagement with relevant materials by constructing an external representation of related knowledge. Several studies suggested that a well-designed external representation, such as concept maps, is useful and could be used for improving the accuracy of problem solving (Hu et al., 2021; Kremer, 1988; Zhang, 1997). A concept map could visually represent important concepts for problem solving that could be more easily retrieved and shared to aid the inquiry process, thus may increase the cognitive presence. However, skimming the concept map alone is insufficient. Learners need to actively organize information by creating a concept map. In the context of collaborative learning, recreating concept map form given components based on teacher-created map is more effective in increasing problem-related conversations in discussion (Pinandito et al., 2021). Moreover, using a teacher-created map is an effective approach to concept mapping (Willerman & Mac Harg, 1991).

A type of concept mapping known as kit-build concept mapping (KBCM) enables learners to reconstruct concept maps from components based on a teacher-created map, receive immediate feedback, and reflect their state of understanding (Yamasaki et al., 2010). Therefore, it is one of the promising alternatives to be included in preparatory activities for increasing cognitive presence. Moreover, learners could also be provided access to the goal map during the discussion for reference that scaffolds their discussion process, i.e., learners may share the map when encountering difficulties during the discussion because the map is worth sharing.

KBCM has been used for supporting discussion in past studies, e.g., Pinandito et al. (2021). However, whether KBCM as a preparatory activity before the discussion, as well as the provision of a teacher-created goal map as a reference during the inquiry process, is more effective compared to other alternatives needs to be investigated. To address this gap, this study aims at comparing the use of KBCM and summary writing in a CoI-based discussion for fostering cognitive presence. The following research question is addressed: How different is the cognitive presence shown in the discussion by learners who did the KBCM activity compared to learners who did summary writing?

2. Related Works

2.1 Strategies for Fostering Cognitive Presence

One of the challenges for realizing CoI-based discussion is preventing inactivity and increasing the quality of discussion; hence, fostering cognitive presence is necessary. Prior studies have proposed several approaches for addressing this issue, namely: (a) facilitation by teacher; (b) facilitation by peers; and (c) designing the activity by adding certain extra activities or certain technologies, e.g., the use of certain tools for aiding the discussion, etc. (Moore & Miller, 2022). Providing facilitation by peers and instructors during the discussion are possible but insufficient.

Despite being the most popular form of facilitation, the effectiveness of instructor facilitation is still inconclusive according to Cho and Tobias (2016). Furthermore, instructor facilitation during the discussion requires the instructor to gain the current state of the learners' understanding and constantly monitor their progress during the discussion, which is very impractical when a large number of learners are involved. In the case of peer facilitation, it is difficult to prepare all participants before discussion to take on the role of facilitator, and there is no correlation between it and some processes that are categorized as cognitive presence, according to a study by Chen et al. (2019). Learners' unpreparedness to be facilitators may also hinder the effectiveness of the facilitation.

Another alternative is providing extra activities or technologies into the discussion activity to make learners more engaged with the contents (Saadatmand et al., 2017). This comprises of activities or the use of technologies before and during the discussion. This study focuses on investigating the effectiveness of a preparatory activity using summary writing and KBCM for fostering cognitive presence.

2.2 Kit-Build Concept Map

KBCM is an approach to concept mapping in which learners try to reconstruct a teacher-created map (goal map) using given components without seeing the teacher-created map (Yamasaki et al., 2010). In the process, KBCM enables automatic diagnosis of understanding which provides the learners with feedback on whether they correctly or incorrectly link the given components (Hirashima et al., 2011). Moreover, after the reconstruction activity, the goal map could be provided to be accessed throughout the discussion, which may be shared and referred to when learners need to confirm their understanding of relevant concepts during the discussion. Prior studies have shown evidence that KBCM could improve learning achievements, for example, learners who used KBCM showed better knowledge retention and higher-order thinking in problem solving (Alkhateeb et al., 2015; Nurmaya et al., 2023). KBCM is proposed as a preparatory activity for improving cognitive presence based on the assumption that KBCM could increase awareness of common terms and concepts related to the discussion topic. As a result, it is expected that the learners could productively discuss the given problem, thus achieving a high level of cognitive presence.

3. Methods

3.1 Learning Context

Two linear algebra classes (Class A & Class B) consisting of computer science undergraduate students at an Indonesian public university were involved in this study. Both classes consisted of different numbers of students (n_A = 70; n_B = 20) because the students could freely register for classes based on their convenience as long as the classes were available at the beginning of the academic semester. Some students did not participate fully in the learning activity. Therefore, only a part of the students who did all the necessary activities were included in the analysis (n_A = 48; n_B = 13). Class A was designated as the experimental (KBCM) group, while Class B was designated as the control (summary writing) group. The second and the third authors worked together in designing the course, developing the test items, and teaching the classes. They are both domain experts in linear algebra.

Both classes received identical learning materials and teaching styles. The learning activities of both classes included lecture sessions and asynchronous online discussion activities offered in the Moodle forum (https://moodle.org/). The learning materials used in the activity related to this study were about vectors and general vector space. The learning goal of this topic was the ability to demonstrate whether a mathematical object could be viewed as a vector through sustained discussion via the forum, in which collaborative knowledge construction is expected to happen. The CoI framework was implemented to design the discussion activity to achieve this goal. To conduct the discussion activity, students in the KBCM group were divided into 10 discussion groups, while the students in the summary writing group were divided into three discussion groups. Each group consisted of six to seven participants. Both classes had similar level of basic knowledge regarding the discussion topic at the beginning of the activity.

3.2 Procedures

The experiment conducted in this study took place in a real class environment. The activities undertaken and the different treatments received by the control group and the experimental group in this study are illustrated in Figure 1.

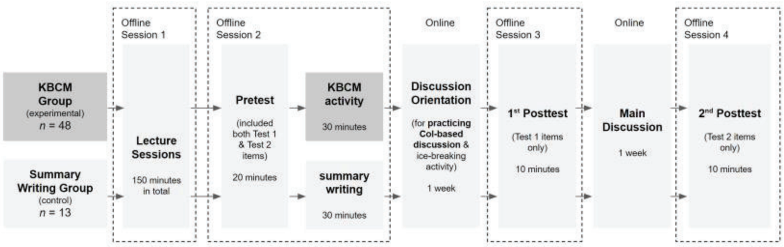

Figure 1. Activities Undertaken in This Study

At the beginning of this experiment, both the KBCM and summary writing groups participated in classroom lecture sessions that introduced them to the concepts of vectors. After attending the class, both groups participated in a session in which a pretest was administered. The pretest served as a baseline for: (a) measuring the basic knowledge about vectors (Test 1), which is expected to be mastered by the students before the discussion; and (b) measuring the procedural knowledge about mathematical proof related to vector space (Test 2), which is expected to be acquired after the discussion (see Subsection 3.3.1).

After completing the pretest, the students in the KBCM group were instructed to individually reconstruct a concept map using given components, while the students in the summary writing group were instructed to write a structured summary about the learning materials. Both groups received identical learning materials. The concept map contains keywords derived from the learning materials, while the summary template provides subtopics as hints for making the summary. Both the concept map and the summary template cover the same learning topics and scope. Figure 2 illustrates the comparison of KBCM and summary writing activities.

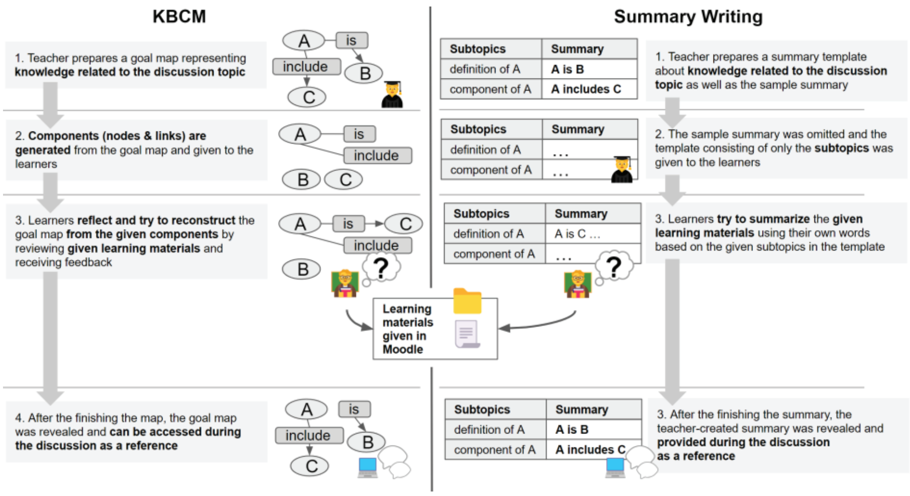

Figure 2. Comparison of KBCM and Summary Writing Activity

Afterwards, both KBCM and summary writing groups participated in discussion orientation provided via Moodle forum for practicing CoI-based discussion and doing ice-breaking activities as preparation before the main discussion. The discussion orientation is a cognitive apprenticeship training provided to the students to familiarize and train them with CoI processes as suggested in prior studies (Junus, 2017; Junus et al., 2019). This is intended to foster their social and teaching presence.

The first posttest was administered after the discussion orientation, in which only the items from Test 1 were used. The main discussion started as soon as the students completed the first posttest. In the main discussion, the teachers started the discussion thread with a triggering question that needed to be collaboratively solved by the discussion groups. The triggering questions given to each discussion group in the main discussion are different, and their cases are not identical with the cases given in the discussion orientation. For example, this triggering question was posed in the discussion orientation: "Suppose you are given the following entity: $a = (1, 5, 12, \frac{x}{27})$ and $k, x \in \mathbb{R}$. What is a?" In contrast, the following is used in the main discussion: "You are given the set $C[0, 2]$ (the set of all continuous functions on the interval $[0, 2]$). How can you think of a function, such as $y = 3x + \cos x$, as a vector? Relate it to what you have learned in the concept map activity."

Moreover, the students from the KBCM group were provided with the teacher map and were explicitly asked to refer to the concept map. In contrast, the students from the summary writing group were also instructed the same but an instructor-created summary was provided instead. From this point, the experimental group could access the teacher map to aid their discussion process. Both the teacher map and teacher-generated summary have identical contents related to the discussion. At the end of the experiment, both groups were instructed to complete the second posttest consisting of Test 2 items.

3.3 Data Analysis

3.3.1 Learning Performance: Pretest & Posttest Questions

Two tests were administered to measure students' learning achievement. Test 1 consists of 10 multiple-choice question (MCQ) items that measure students' understanding of basic knowledge about vectors (i.e., how to represent a vector in R^2, basic arithmetic involving 2 vectors, etc.). The test items were self-developed, and their content was validated by the teachers of the linear algebra classes (the second & the third authors). On the other hand, Test 2 comprises 10 MCQ items measuring students' understanding of procedural knowledge, that is, their ability to analyze the logically valid and correct mathematical proofs showing a mathematical object as a vector. Tests of significant differences between the pretest and posttest scores for Test 1 were used to investigate whether the KBCM group improved their understanding of basic knowledge before conducting the discussion compared to the summary writing group. On the other hand, Test 2 results were used to investigate whether there are differences between the groups in terms of the ability to analyze a mathematical proof at the end of all activities.

3.3.2 Discussion Quality Instrument: Cognitive Presence Coding Scheme

The coding scheme was developed to identify messages that showed cognitive presence based on Garrison et al. (2001) and Junus (2023). In this preliminary study, the coding process was conducted using MAXQDA by a coder who has experience in the CoI framework. The final codes were analyzed by obtaining the frequency of cognitive presence messages for each student, and the average was calculated for the KBCM and summary groups. A significance test was conducted on the data to answer the research question.

4. Results and Discussion

4.1 Pretest and Posttest Scores

The pretest and posttest scores for both Test 1 and Test 2 were analyzed. The descriptive statistics for the pretest and posttest scores are shown in Table 1.

Table 1. *Descriptive Statistics of Pretest and Posttest Scores*

Group	Tests	Data	Min	Max	Median	Mean	S.D.
KBCM	Test 1	Pretest	50.00	100.00	90.00	90.42	11.66
(n = 48)		Posttest	40.00	100.00	100.00	96.67	10.59
		Learning Gain	-0.56	1.00	0.00	0.42	0.52
	Test 2	Pretest	0.00	100.00	80.00	66.25	35.05
		Posttest	0.00	100.00	100.00	79.58	36.26
		Learning Gain	-1.00	1.00	0.00	0.25	0.63
Summary	Test 1	Pretest	70.00	100.00	80.00	83.08	11.09
Writing		Posttest	80.00	100.00	100.00	93.85	7.68
(n = 13)		Learning Gain	-0.20	1.00	0.67	0.61	0.45
	Test 2	Pretest	0.00	100.00	50.00	50.77	34.99
		Posttest	0.00	100.00	80.00	60.77	40.92
		Learning Gain	-1.00	1.00	0.25	0.35	0.65

Non-parametric tests (Mann-Whitney & Wilcoxon tests) were conducted on the pretest and posttest scores for both Test 1 and Test 2 to compare the learning achievement of KBCM and summary writing groups due to the existence of a non-normal distribution in some data. To minimize the probability of false positives in multiple comparisons, all p values from Test 1 and Test 2 data analyses were adjusted using Holm's method. An overview of the results of the non-parametric tests is shown in Figure 3.

As shown in Figure 3, both groups showed the same level of understanding regarding basic and procedural knowledge prior to and after the discussion. Moreover, there is also no significant difference in the learning gain of both groups for Test 1 and Test 2. There is an indication that the large difference in sample sizes between both groups affected this result. This is a limitation of this study due to the experimentation conducted in real-class settings, which made controlling the number of students who enrolled in a class to ensure a similar sample size rather difficult. Thus, whether the treatment contributed to these results is inconclusive. However, despite having the same level of basic and procedural knowledge, the KBCM group showed a different discussion output in terms of cognitive presence.

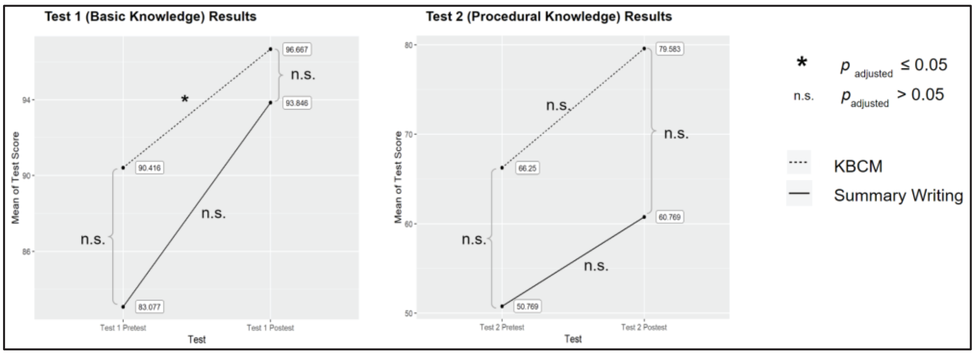

Figure 3. Pretest and Posttest Scores Comparison

4.2 Cognitive Presence Frequency

At the end of the activity, in total, 256 messages were retrieved (237 messages in the experimental group's discussion threads; 19 messages in the control group's discussion threads). In addition, the coding process resulted in 243 messages categorized as posts containing cognitive presence. After the discussion transcripts of all groups were coded, the frequency of messages that contain cognitive presence was calculated for each participant. The means of the frequency from both groups were compared using Mann-Whitney test. The descriptive statistics of the result are presented in Table 2.

Table 2. *Descriptive Statistics of Cognitive Presence Messages*

Group	Number of CP Messages	Min*	Max*	Median*	Mean*	S.D.*
KBCM (*n* = 48)	225	1.00	18.00	4.00	4.69	3.55
Summary Writing (*n* = 13)	18	0.00	3.00	1.00	1.38	0.77

Note. * Statistics presented are based on the number of messages per participants

Both groups showed an identical ratio of cognitive presence messages compared to non-cognitive presence messages (95% of messages containing cognitive presence & 5% of messages excluding cognitive presence). This indicates that both groups were focused on discussing the problem. However, further analysis regarding the frequency of cognitive presence messages frequency per participant revealed that the intensity of the discussion differed. There is a significant difference between both groups' frequency of cognitive presence messages per participant, as shown in Figure 4.

The KBCM group significantly had a higher frequency compared to the summary writing group ($p < 0.0001$). This result showed that, despite having an identical ratio of cognitive presence messages, the KBCM group showed significantly more interaction related to understanding and solving the given problem. Participants in the KBCM group contributed more to the discussion about the problem than the summary writing group. This indicates that they have a better ability to discuss the problem in more detail than the summary writing group. This result supports a prior study that showed KBCM as an effective tool to keep learners focused on discussing the learning contents (Pinandito et al., 2021).

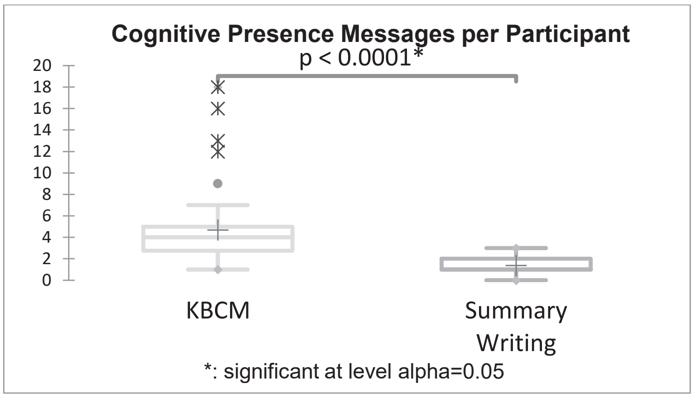

Figure 4. Comparison of the Cognitive Presence Messages per Participant

The characteristic of the instructor-generated concept map as an effective external representation of basic knowledge for the discussion might have contributed to this finding. The discussion required the students to connect various concepts (i.e., the definition of vectors, their axioms, & how to prove certain axioms). By referring to the instructor-generated map during the discussion, the learners could easily resolve misconceptions about core concepts related to the problems they were discussing. In contrast, by referring to the text representation of the instructor-provided summary, the students who did not use KBCM might have more difficulty in finding the connections between important concepts. Prior studies suggested that visual representation of knowledge has the potential to be better than textual representation (Barideaux et al., 2013; Kremer, 1988).

In addition, the characteristics of the KBCM as an activity for reconstructing a teacher-created concept map might also have contributed to this finding. The concept map, as a teacher-provided external representation of knowledge that needs to be reconstructed by learners from given components, provides an opportunity to make the students aware of the correct terms used in discussion (i.e., what a vector is, how it is represented, etc.) better than just seeing an external representation. They could be aware of the common terms used to describe something related to the topics. Even though confusion might occur during the discussion, they could use the same terms to refer to an object when engaging in the discussion. Moreover, having experience in reconstructing the map just before the discussion might reinforce memorization and awareness of what concepts are relevant to the discussion.

A prior study had suggested the effectiveness of KBCM in improving knowledge retention through increasing access to long-term memory (Alkhateeb et al., 2015). This might have resulted in better retention of basic knowledge during the discussion period. However, this assumption needs further investigation as the delay test on the basic knowledge (Test 1) was not yet included after the discussion. As a result of being enabled to be aware of common terms, learners in the KBCM group could resolve differences, reach consensus easily, focus the discussion on how to solve the problem, and explore many possible solutions, instead of being passive due to a lack of clarity about what and how to discuss. In short, by using the same terms and achieving intellectual convergence on basic knowledge before the discussion, reaching a common understanding about what to do to solve the given problem might become easier. This result suggests that KBCM has a potential enable learners to have a more productive problem-solving discussion. In this case, KBCM could provide learners with the opportunity to develop ability to inquire more when conducting collaborative problem solving, which is one of the necessary characteristics that the learners should acquire in higher-education.

5. Conclusion

This study compared the use of KBCM and summary writing activities as discussion preparation aimed at increasing learners' cognitive presence and learning achievements (basic & procedural knowledge related to the discussion topic). The results showed that both experimental and control groups had an identical level of understanding about basic knowledge after the treatment as well as an identical level of procedural knowledge after the discussion. However, those who did KBCM activity showed a significantly higher rate of cognitive presence messages in the discussion due to increased awareness of common terms represented in the concept map. To conclude, KBCM presents a potential for increasing learners' cognitive presence in a CoI-based discussion.

However, the result could not be generalized due to several factors that might affect the outcomes. There are some limitations that resulted from conducting the experiment in real-class environments. Firstly, there is a difference in the number of students in both classes due to the university's policy regarding enrollment. Secondly, the experiment is limited to the subject of linear algebra. Thus, conducting the experiment in different educational contexts by involving a near equal number of participants in both the experimental and control groups is needed. Moreover, future studies could also investigate the effect of the proposed treatments on particular practical inquiry processes of cognitive presence (i.e., exploration, integration, etc.).

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