# Fostering Higher-Level Inquiry in Online Asynchronous Discussion with Kit-Build Concept Mapping: A Case in Learning Linear Algebra

Lintang Matahari Hasani
*Graduate School of Advanced Science and Engineering, Hiroshima University, Japan*

Kasiyah Junus
*Faculty of Computer Science, Universitas Indonesia, Indonesia*

Lia Sadita
*Research Center for Data and Information Sciences, National Research and Innovation Agency (BRIN), Indonesia*

Tsukasa Hirashima
*Graduate School of Advanced Science and Engineering, Hiroshima University, Japan*

Yusuke Hayashi
*Graduate School of Advanced Science and Engineering, Hiroshima University, Japan*

**Abstract**
Online collaborative learning (OCL) based on the community of inquiry (CoI) framework is often implemented in the form of an online discussion activity for teaching subjects that require learners to revise their understandings and invent ways to solve problems. However, implementing OCL is challenging due to the difficulty of fostering higher-level inquiry stages. Such an issue could hinder the effectiveness of the discussion and might lead to low participation. Prior studies on OCL showed that facilitation strategies are insufficient for fostering higher-level inquiry stages. There is a need for an alternative strategy that could complement the existing approaches. Providing a preparatory activity that increases engagement with learning contents related to the discussion topic through a kit-build concept mapping (KBCM) activity could enable the participants to engage in a productive discussion by increasing their awareness of discussion-related concepts and their relationship. Such an activity may help the participants progress through the inquiry stages. This study aims to propose a preparatory activity for organizing knowledge using KBCM to support learners in advancing through practical inquiry stages during the discussion. In this article, we report the implementation of the proposed method in an online discussion about linear algebra. The results show that participants who did KBCM showed a higher rate of triggering event, exploration, and integration compared to those who did summary writing. Therefore, KBCM has the potential to help learners progress through inquiry stages in a more productive way up until integration compared to the traditional method of writing a structured summary.

*Keywords:* Online collaborative learning, community of inquiry, cognitive presence, online discussion, kit-build concept mapping, structured summary

Hasani, L. M., Junus, K., Sadita, L., Hirashima, T., & Hayashi, Y. (2025). Fostering higher-level inquiry in online asynchronous discussion with kit-build concept mapping: A case in learning linear algebra. *Online Learning, 29(1),* 323–346. DOI: https://doi.org/10.24059/olj.v29i1.4379

Online collaborative learning (OCL) is a popular learning model that has been implemented in various educational contexts across the globe. In OCL, learners are expected to work together to generate, organize, and achieve convergence of ideas; thus, they have the opportunity to develop understanding beyond what they could achieve alone (Harasim, 2017; Mende et al., 2021). Therefore, OCL is suitable for teaching subjects that require learners to collaboratively explore ways to solve problems, think critically through identifying both their misconceptions and others', revise their understanding, and gain deeper knowledge.

One of the most popular ways of implementing OCL is an online asynchronous discussion conducted in a forum, usually by applying the community of inquiry (CoI) framework, which is also the most widely researched framework in online learning (Bates, 2022; Garrison et al., 2001; Maranna et al., 2022; Park & Shea, 2020; Valverde-Berrocoso et al., 2020). In the forum, the learners are usually instructed to discuss a particular topic by giving them a triggering question or case study consisting of a problem that fits for collaborative problem-solving. This kind of activity offers flexibility and the potential for enhancing learning (McCarron et al., 2021).

According to the CoI framework, the learners are expected to exhibit three presences that make up their learning experience during the discussion: social presence (e.g., expressing their authentic self when interacting with others), cognitive presence (e.g., thinking critically in problem-solving activities), and teaching presence (e.g., facilitating the activity) (Garrison, 2016). Furthermore, these four iterative stages define different levels of cognitive processes that make up the cognitive presence: *triggering event*—posing, identifying, and confirming problems; *exploration*—sharing resources and transactions of ideas; *integration*—synthesizing various ideas; and *resolution*—applying and defending solutions (Garrison, 2016). *Triggering event* and *exploration* are considered lower-level stages, while *integration* and *resolution* are considered higher-level stages because they require higher-order thinking (Chen et al., 2019).

Achieving higher-level inquiry stages is indeed not the goal for all instructions (Olesova et al., 2022). Such a goal depends on the intended purpose of the instruction (Garrison, 2016). For example, in the context of teaching a subject that requires learners to revise their understanding through inventing ways to solve problems, achieving higher-level inquiry stages is necessary because thinking critically about one's understanding as well as the others' is needed when doing such activities (e.g., synthesizing and defending arguments). Failing to promote higher-order thinking in an online discussion activity may be a detriment to students' learning (Koszalka et al., 2021). In addition, it is also important for such an inquiry to begin with understanding what the problem is at the very beginning of the discussion. Spending sufficient time to confirm what the problem is and how such a problem could be solved is necessary before moving into a deeper discussion regarding the proposed solutions (Garrison, 2016; Vaughan & Garrison, 2005).

Despite the popularity of online asynchronous forums as an OCL environment for conducting these activities, the forum itself does not necessarily foster effective and productive discussion characterized by high occurrences of cognitive presence (Moore & Miller, 2022; Sadaf & Olesova, 2017). Prior studies reported that, in some cases, learners showed inactivity or less productive discussion in the form of "serial" or sequential monologues (Fung, 2004; Garrison & Cleveland-Innes, 2005; Pawan et al., 2003). Sequential monologues indicate that the learners are only responding to the triggering question posed by the teacher by posting their opinions without responding to the others; thus, collaboration does not happen and the learners do not gain deeper understanding (Garrison & Cleveland-Innes, 2005). Some studies also reported that learners tend to remain at lower-level inquiry stages, like exploration (Bradley et al., 2008; Rourke & Kanuka, 2009). A study also showed very few messages indicating higher-level inquiry stages compared to the former (Garrison et al., 2001). In addition, relatively few triggering event messages were exhibited by the learners in other studies, which may indicate that learners tend to "jump" to stating the solution without confirming what the problem is or showing fewer cues indicating their sense of puzzlement (McKlin et al., 2001; Vaughan & Garrison, 2005).

To address these issues, prior studies have proposed various strategies. It has been suggested that changing the instructional design and providing facilitation could change the pattern of cognitive presence in online discussion. For example, peer and instructor facilitation have been proposed in some prior studies to foster cognitive presence and achieve effective online discussion (An et al., 2009; Chen et al., 2019; Oyarzun & Martin, 2023). However, a study suggested that such facilitations are still inconclusive (Moore & Miller, 2022). Moreover, in the case of peer facilitation, learners who are novice discussion participants may not function effectively as facilitators (Weinberger et al., 2005). On the other hand, too much instructor presence may not necessarily lead to more interaction among students (An et al., 2009). Insignificant instructor presence, although it may lead to freer discussion, may not lead to effective problem-solving, e.g., most of the discussion content is free-talking and unrelated to the problem, with misconceptions being ignored. Additionally, intensive instructor facilitation may become impractical in large classes due to the overwhelming number of messages (Lee et al., 2022).

Another study proposed that providing training before the discussion to prepare the participants could enhance their readiness to engage in productive discussion with high cognitive presence (Junus et al., 2019). However, the mentioned study did not address the issue of whether such training could lead to a discussion with a higher rate of higher-level inquiry stages. Therefore, it is still inconclusive that training alone could significantly foster a higher rate of such occurrences.

Another alternative is providing activities that could increase engagement with the learning content that is related to the discussion topic (Saadatmand et al., 2017). It is also necessary to enable deep personal reflection, which is one of the factors that affect cognitive presence (Maranna et al., 2022). An example that could cater to this need is providing a preparatory activity prior to the discussion in which the learners are instructed to organize and deepen their understanding of the basic knowledge necessary for engaging in the discussion, which they previously received from attending lecture sessions, reading books, etc. Such activity could be done by making summaries or concept maps that represent the knowledge related to the discussion topic.

Concept mapping is an activity of organizing information that could enable learners to process complex problems, have a common vocabulary, and allow information to be easily transmitted by referring to a concept map (Colosimo & Fitzgibbons, 2012; Novak & Cañas, 2006). A concept map visually represents the information included in learning materials as a web of interconnected concepts, thus making underlying connections between concepts explicit for learners.

However, in the context of supporting a deep inquiry involving abstract concepts (e.g., discussion about mathematics), instructing learners only to read through the map is not sufficient for making them aware of underlying connections between several concepts. Learners are expected to be aware of the relationship between the concepts in such a situation. By only reading the map, the learners may skip important connections between concepts. Moreover, making a concept map from scratch risks the possibility of creating meaningless or false propositions due to difficulties in making the propositions (Nurmaya et al., 2023b).

A type of concept mapping that could help learners become aware of connections between concepts and has been adopted in the context of OCL is kit-build concept mapping (KBCM). KBCM is an activity of organizing knowledge in which the learners reconstruct a teacher-created concept map from given components (nodes and links) while receiving immediate feedback during the attempt (Yamasaki et al., 2010). Such nodes and links represent propositions included in the learning materials related to the discussion topic. When reconstructing the map, learners could achieve awareness of the connections between concepts by actively connecting the given component and reflecting their understanding. KBCM could help learners, including lower to middle achievers, to achieve such awareness due to being provided with components as a scaffold, i.e., the learners are not required to extract and express the structure of the domain knowledge by themselves. Thus, KBCM is a promising alternative for engaging learners with discussion-related materials as preparation before online discussion.

Reconstructing a teacher-created concept map (KBCM) could lead to a higher rate of cognitive presence-related messages compared to writing a structured summary (Hasani et al., 2023). Prior studies also presented evidence of a high number of problem-focused messages among learners who used KBCM in OCL (Nurmaya et al., 2023a; Pinandito et al., 2021). An increased awareness of common concepts and terms from recognizing the keywords and propositions in the concept map reconstruction activity is one factor that could potentially lead to a productive discussion with a higher rate of cognitive presence (Hasani et al., 2023).

A productive discussion does not necessarily mean deeper inquiry for solving problems, which is indicated by a high number of messages showing higher-level inquiry stages. Thus, there is a need for an alternative way to prepare the learners to engage in a meaningful and productive discussion and achieve higher-level inquiry stages. A meaningful and deep inquiry is characterized by a sustained transaction of ideas that enables learners to gain a deep understanding (Garrison, 2016). Higher occurrences of higher-level inquiry stages in the discussion (integration & resolution) as well as fostering problem confirmation at the beginning of the inquiry (triggering event) indicate such an inquiry. To address this issue, this study is aimed at comparing the effect of providing knowledge organizing activities in the form of summary writing and KBCM on the occurrences of triggering event, exploration, integration, and resolution, which make up the cognitive presence within the discussion. Moreover, the pattern of each inquiry stage across the discussion period is analyzed. By comparing the discussion of the KBCM and summary writing groups, the following research questions (RQs) are addressed:

RQ1: To what extent did the number of messages categorized as triggering event, exploration, integration, and resolution differ among the groups?

RQ2: To what extent did the pattern of occurrences of triggering event, exploration, integration, and resolution across the discussion period differ among the groups?

This study aims to contribute to the improvement of CoI-based online discussion implementation. As a case study, an online discussion about linear algebra was conducted and involved both the learners who used KBCM as well as summary writing. RQ1 is addressed in this study to evaluate the extent of learners' engagement throughout inquiry stages in the discussion (i.e., higher-level thinking in online discussion). Whether both groups showed significantly different rates of messages for each inquiry stage is addressed in RQ1. Moreover, RQ2 is addressed to investigate the dynamics of how learners engage the problem in each inquiry stage across the discussion period. Whether both groups showed a pattern of occurrence for each inquiry stage across the discussion period that resembles a deep inquiry is addressed in RQ2.

# Theoretical Framework

### *The Community of Inquiry (CoI) Framework and Practical Inquiry*

The CoI framework provides a theoretical basis for the elements of learning experience in an inquiry-based learning activity. Such a type of collaborative learning is based on the notion of "transaction of ideas" conducted in a text-based asynchronous online medium, in which learners co-construct knowledge through a sustained and meaningful discourse (Garrison, 2016). The framework was developed based on social constructivist theory (Garrison et al., 1999). In the context of OCL, the CoI framework defines three elements that make up the whole learning experience:

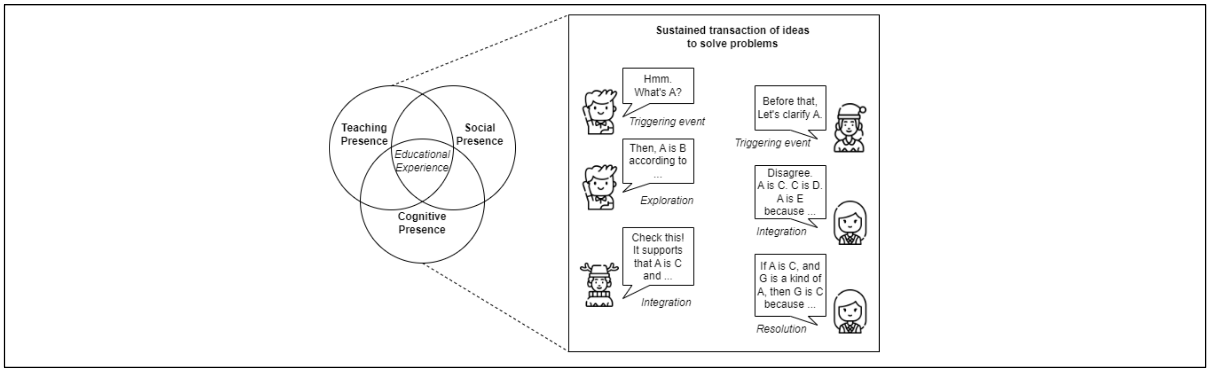
(a) social presence—bringing authentic self into the online settings to develop interpersonal relationships and enable the transaction of ideas
(b) cognitive presence—conducting problem-solving through critical thinking in a sustained and meaningful discourse
(c) teaching presence—designing and facilitating the activity for achieving goals.

Figure 1 illustrates an OCL activity based on this framework

The inquiry activities that occurred in a CoI are further described in the practical inquiry model, which illustrates the operationalization of the cognitive presence (Garrison, 2016). At first, learners are expected to collaboratively address the triggering question by confirming their understanding of the problem as well as the expected solutions, i.e., triggering event. After agreeing on the nature of the problem and the expected solutions, the learners are expected to discuss further by sharing relevant resources and agreeing or disagreeing on particular ideas, i.e., exploration. They could also elaborate on more than one idea, make logical inferences, and conclude discourse, i.e., integration. If they are able to conduct much higher-order thinking, they may apply solutions in various contexts and defend them, i.e., resolution.

**Figure 1**

*The CoI Framework*



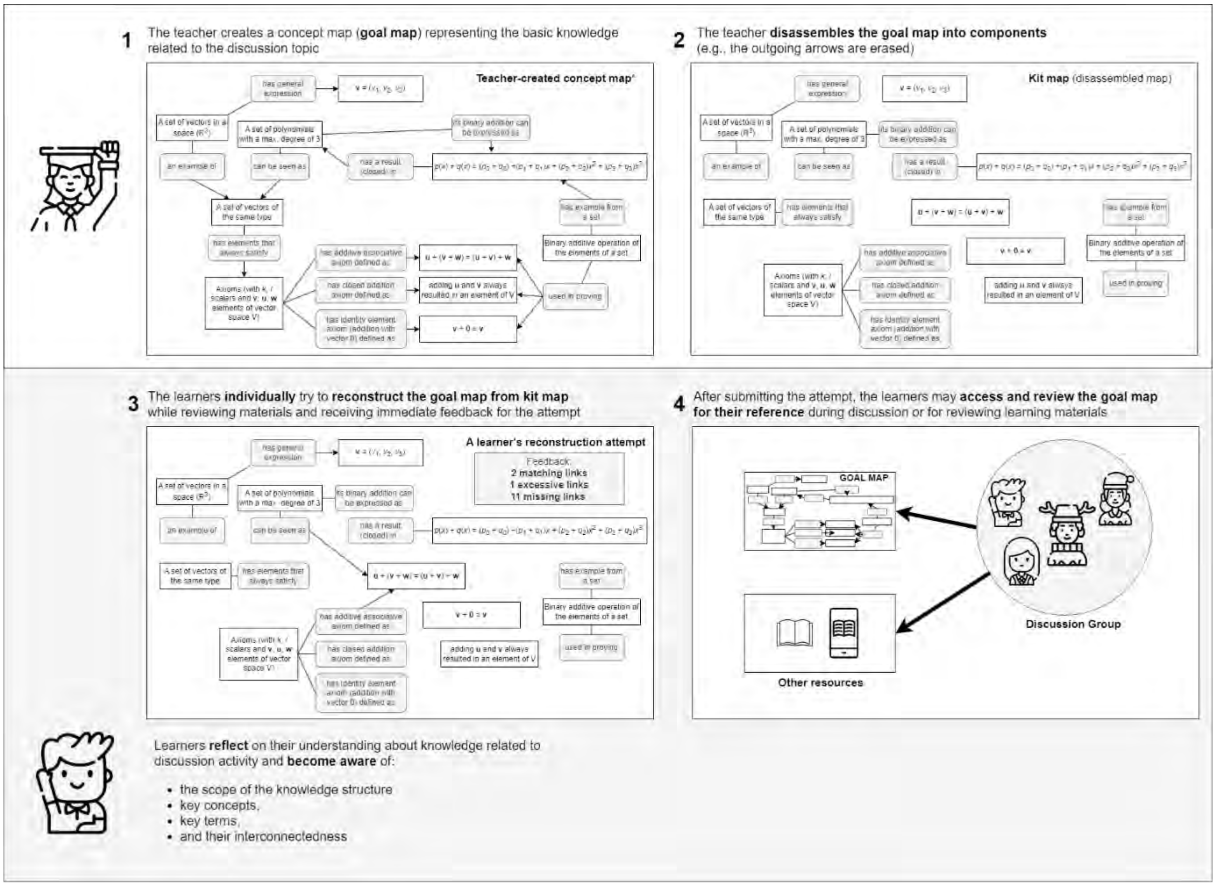

*Note.* Parts of the illustration were adapted from "About the Framework: An Introduction to the Community of Inquiry," by Centre for Distance Education at Athabasca University, 2021 (http://thecommunityofinquiry.org/coi). CC BY-SA 4.0. This figure has been designed using images from Flaticon.com.

### ***KBCM***

Concept mapping is one of the knowledge-organizing activities that has gained popularity in various educational contexts. As a form of knowledge representation, a concept map visually represents knowledge contents (propositions) as links and nodes (Novak & Cañas, 2006). A type of concept mapping activity that has been proven to be effective for supporting learning in several contexts is KBCM. In KBCM, learners reconstruct a teacher-created concept map from given components (links and nodes) and receive immediate feedback for their attempts (Hirashima et al., 2011; Yamasaki et al., 2010). A KBCM activity usually includes the following steps: (a) a teacher prepares a goal map that represents the knowledge structure of a learning material; (b) the goal map is disassembled into a kit (parts consisting of links and nodes); (c) the learners try to reassemble the goal map from the kit and receive feedback in the process (Yamasaki et al., 2010). Such an activity enables learners to reflect on their understanding while reviewing learning materials. Figure 2 illustrates an excerpt of the teacher-created map (goal map), the disassembled goal map (kit map), and how they can be used to support an OCL activity such as online discussion.

**Figure 2**

*The Use of KBCM as a Preparatory Activity for Online Discussion*




*Note.* This figure has been designed using images from Flaticon.com.

KBCM activities have been included to complement OCL in some prior studies and have shown the potential to support the inquiry process. In this context, the use of KBCM includes: (a) KBCM as a preparatory activity for online discussion based on the CoI framework (Hasani et al., 2023); and (b) KBCM for collaborative concept-mapping (Nurmaya et al., 2023a; Pinandito et al., 2021). A prior study by Hasani et al. (2023) presented evidence of the potential of KBCM compared to summary writing as a preparatory activity for online discussion. In the case of KBCM, an increased awareness of key terms and concepts related to discussion, as well as their interconnectedness, is shown to be a potential enabler of a productive discussion. In contrast, the learners who used summary writing might have experienced difficulties recognizing the common terms despite being given feedback after the attempt because they could freely use any terms they wanted when writing the summary. Recognizing common terms and using them during the discussion might help learners discuss more productively; thus, it may result in a higher rate of messages containing cognitive presence.

# Methods

This study consists of a follow-up analysis of the data gathered in a related prior study by Hasani et al. (2023), which implemented a quasi-experimental approach involving an experiment conducted in real-classroom settings. The following subsections describe the learning context, the procedures, and the data analysis method used in this study.

### *Learning Context*

The experiment involved 61 students from two linear algebra classes (Class A and Class B) offered by computer science and information systems programs at a public university. Class A and Class B were assigned as the experimental group (KBCM group) and the control group (summary writing group), respectively. Both classes had a different number of enrolled students due to the university's policy of allowing students to choose any available classes based on their convenience. This affected the difference in the sample size between the experimental group and the control group (Class A: 48 students; Class B: 13 students). The participants' informed consent was obtained prior to the experiment.
In addition, ethical clearance and approval from the teaching team were obtained. Table 1 shows the demographics of the participants.

**Table 1**

*Demographics of the Participants*

| | **Class A** (KBCM; *n* = 48) | **Class B** (summary writing; *n* = 13) |
|---|---|---|
| **Gender** | | |
| Male | 39 | 8 |
| Female | 9 | 5 |
| **Batch** | | |
| 2019 | 0 | 1 |
| 2020 | 0 | 1 |
| 2021 | 0 | 1 |
| 2022 | 48 | 10 |

Two different lecturers who had more than four years of experience in teaching linear algebra and had prior experience in delivering online collaborative learning based on the CoI framework taught the two classes. In this experiment, they closely worked together in designing and delivering the class to ensure that both classes received the same learning materials, teaching styles, workload, and learning environment. An online forum provided by Moodle (https://moodle.org) was used as the online collaborative environment in both classes.

The learning topic that was addressed during the experiment was general vector space. The learning goals for this topic were as follows: The students are able to provide a valid mathematical proof for whether a given mathematical object could be seen as a vector. To be able to attain this goal, the students are expected to

(a) understand the principles of arithmetics related to vectors in Euclidean spaces ($R^2$ and $R^3$)
(b) be able to use binary set operations for defining arithmetic operations involving vectors
(c) be able to generalize such principles to vectors in *n*-space ($R^n$)
(d) be able to recognize whether a set of mathematical objects has a similar algebraic structure to the aforementioned set of vectors
(e) be able to provide a valid mathematical proof using binary set operations to show whether a given set of mathematical objects has such a structure by referring to the 10 axioms of vector space

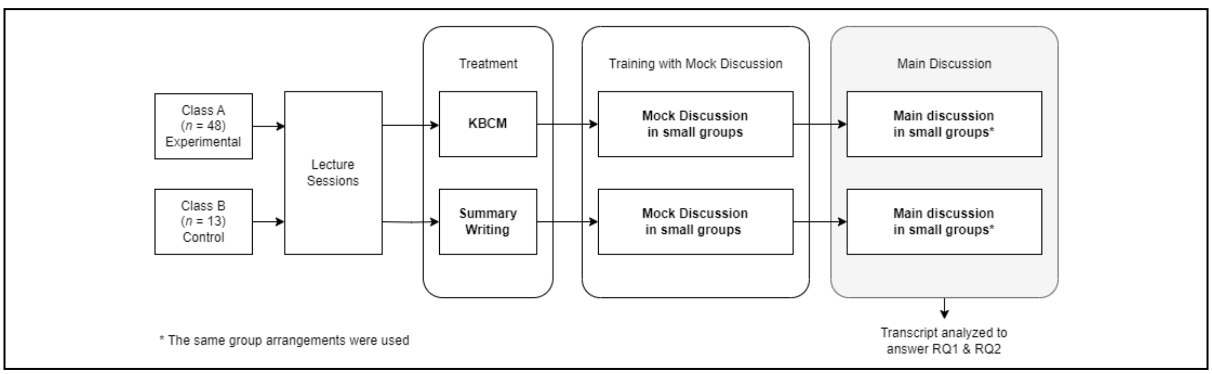
Points (a) and (b) describe the basic knowledge necessary to perform points (c) through (e), which are the expected acquired knowledge after participating in the discussion.
The following subsection describes the discussion and other related activities.

***Procedures***

The following Figure 3 illustrates the steps taken in this study, as specified in Hasani et al. (2023). At first, both the KBCM group and the summary writing group were provided with identical but separate lecture sessions that introduced them to the basic knowledge about vectors and binary set operations, which will be used in the discussion.

**Figure 3**

*Steps Undertaken in This Study*




After attending the lecture session, both groups received the treatment as illustrated in Figure 3. A pretest measuring both the basic knowledge and the expected acquired knowledge was administered to both groups. The test consists of 20 multiple-choice questions covering points (a) through (e). This test served as the baseline to measure whether both groups started at the same level of understanding about the necessary knowledge related to the discussion topic.

After completing the pretest, the students of both groups participated in a CoI training provided in the form of orientation with mock discussion to familiarize them with the know-how of interacting effectively in a CoI-based discussion. The topic of the mock discussion is proving whether a given vector in $R^n$ could also be seen as a vector in a similar way with those in the Euclidean spaces, e.g., a case involving a constant *k* and an entity expressed as $(1, 5, 12, \frac{x}{27})$ with $k, x \in \mathbb{R}$.

During the training, the students in both groups were further divided into smaller discussion groups (six or seven students per group) and were given a triggering question as well as guidance. After completing the training, both groups were administered the first post-test to measure their basic knowledge improvement. Furthermore, both groups participated in the main discussion with the same discussion group arrangement and general instructions (e.g., on using the resources, on how to interact, etc.). The triggering questions given were different from the ones given in the training, e.g., a case involving a constant $k$ and a $m$x$n$ matrix, a polynomial with $n$-degrees, or any objects with vector-like algebraic structure. At the end of the activity, both groups received a second post-test measuring the expected acquired knowledge. The detailed results of the pretest and the post-tests could be accessed in Hasani et al. (2023). The analysis conducted in this study focused on the discussion transcript retrieved from the main discussion. The data used for further analysis are the data that were retrieved from students who completed all activities. The data analysis method is described in the following subsection.

### *Data Analysis*

The discussion transcripts from the main discussion were coded using a coding scheme developed by Junus (2023) for use in a linear algebra online learning context, which is based on a coding scheme by Shea et al. (2010). The codes consist of the stages included in the practical inquiry model: triggering event, exploration, integration, and resolution.

To establish the reliability of the coding result, procedures suggested by Campbell et al. (2013) were conducted. At first, the first coder coded all messages included in the transcripts. Then, the second coder independently coded a randomized sample of messages (30% of all messages), whose labels were omitted. The reliability of the coding results based on the sampled segments of the transcript was measured. The measurement of Brennan and Prediger’s Kappa statistic showed a value of 0.82, which indicated almost perfect agreement according to a benchmark by Landis and Koch (1977). After that, the two coders discussed and achieved agreement regarding the differences, which in turn produced an agreed-upon coding scheme (criteria for labeling messages). Finally, the agreed-upon coding scheme is applied to all messages in the transcripts.

The resulting coding results were used for further analysis involving statistical tests of significance on the average number of messages per participant for each practical inquiry process (answering RQ1). Furthermore, the pattern in the occurrence of the messages across the discussion period is presented to contrast the occurrences of differently-coded messages (answering RQ2). The results are discussed in the following section.

## Results

As reported in Hasani et al. (2023), both KBCM and summary writing groups started from the same level of understanding about both the basic knowledge and the acquired knowledge. Insignificant differences were observed in the average pretest score of both groups. However, both groups showed different discussion patterns. There are 237 and 19 messages retrieved from the KBCM group and summary writing group, respectively.

***Occurrences of Triggering Event, Exploration, Integration, and Resolution***

The retrieved messages were coded as triggering event, exploration, integration, and resolution. A message may indicate more than one practical inquiry stage. The following Table 2 shows the descriptive statistics of the messages classified as triggering event, exploration, integration, and resolution in both the KBCM group and the summary writing group.

**Table 2**

*Descriptive Statistics of Triggering Event, Exploration, Integration, and Resolution Messages*

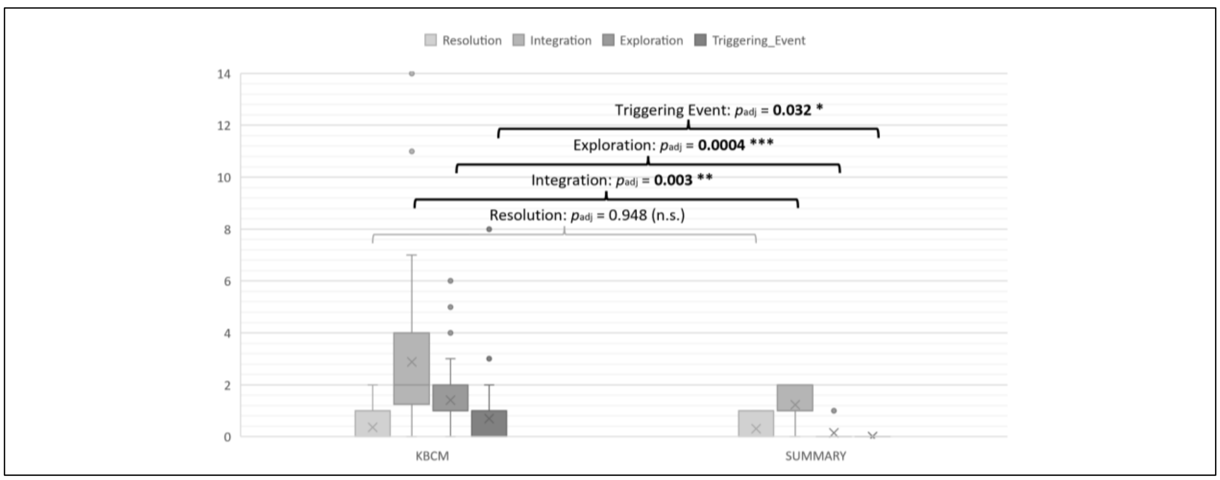
| | Triggering Event | | Exploration | | Integration | | Resolution | |
|---|---|---|---|---|---|---|---|---|
| | KBCM | SW | KBCM | SW | KBCM | SW | KBCM | SW |
| Total messages | 34 | 0 | 68 | 2 | 138 | 16 | 17 | 4 |
| Average | 0.708 | 0.000 | 1.417 | 0.154 | 2.875 | 1.231 | 0.354 | 0.307 |
| Median | 0 | 0 | 1 | 0 | 2 | 1 | 0 | 0 |
| Max. | 8 | 0 | 6 | 1 | 14 | 2 | 2 | 1 |
| Min. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

*Note*. KBCM group ($n$ = 48); SW: Summary writing group ($n$ = 13).

The median number of messages classified as triggering event, exploration, and integration is compared using a statistical non-parametric test (Mann-Whitney test). For the comparison, the $p$-values were adjusted using Holm's method. The results are shown in Figure 4.

**Figure 4**

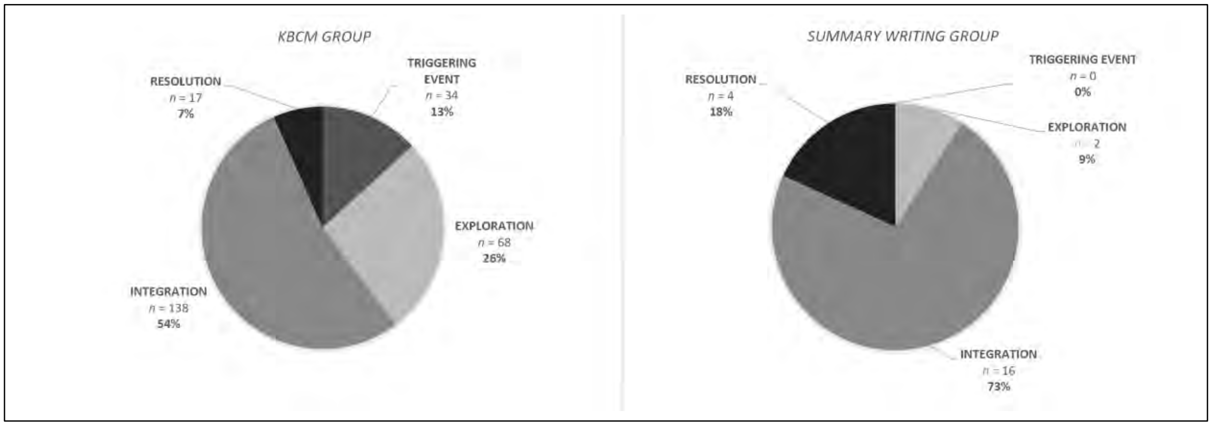
*Number of Messages Classified with Practical Inquiry Processes per Participant*




As shown in Figure 4, the test results after $p$-value adjustment show that KBCM group exhibited significantly higher amount of messages per person classified as triggering event, exploration, and integration compared to summary writing group ($p_{adj} < 0.05$). However, there is no significant difference in the number of resolution-classified messages in both groups. The KBCM group also showed different proportions of messages classified with each practical inquiry processes (see Figure 5).

**Figure 5**

*Proportions of Practical Inquiry Stages*




*Note*. *n* indicates the number of messages.

***Patterns of Overall Occurrence of Inquiry Stages Across Discussion Period***

One important sign of effective inquiry is the high number of triggering event-related activities at the beginning of the discussion (Garrison, 2016). Such activities enable learners to spend sufficient time at the beginning of the discussion reflecting on their understanding of what the problem is and how to solve it before moving into a more rigorous transaction of ideas in the exploration and integration stages. Based on the coding results, the KBCM group and the summary writing group showed different patterns regarding the daily occurrences of each practical inquiry stage (see Table 3).

**Table 3**

*Daily Occurrence of Triggering Event, Exploration, Integration, and Resolution*

| | **Triggering Event** | | **Exploration** | | **Integration** | | **Resolution** | |
|---|---|---|---|---|---|---|---|---|
| | KBCM | S | KBCM | S | KBCM | S | KBCM | S |
| Day 1 | 1 | 0 | 2 | 2 | 1 | 10 | 0 | 1 |
| Day 2 | 15 | 0 | 41 | 0 | 24 | 1 | 0 | 0 |
| Day 3 | 3 | 0 | 5 | 0 | 8 | 0 | 1 | 0 |
| Day 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Day 5 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| Day 6 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| Day 7 | 15 | 0 | 18 | 0 | 73 | 1 | 5 | 0 |
| Day 8 | 0 | 0 | 1 | 0 | 24 | 3 | 6 | 2 |
| Day 9 | 0 | 0 | 0 | 0 | 8 | 0 | 5 | 0 |

Inactivity in the discussion threads of both groups was observed on the fourth and fifth days. During this period, participation attrition might have happened due to learners being distracted to complete assignments from other courses. During the last three days of the discussion period, both groups received a reminder from the instructors to complete the discussion by the ninth day, thus increasing the number of messages.

## Discussion

***RQ1: To what extent did the number of messages categorized as triggering event, exploration, integration, and resolution differ among the groups?***

To answer RQ1, the KBCM group had a higher rate of messages for triggering event, exploration, and integration (see Figure 4). This finding suggests that, under certain conditions, KBCM as a preparatory activity has the potential to foster all lower-level inquiry stages and the higher-level inquiry stage of integration. In addition, the data revealed that (a) the majority of the messages in both the KBCM group and the summary writing group are classified as integration; and (b) there was a lack of triggering event messages in the summary writing group.

Finding (a) stood in contrast with some other studies that reported exploration as the dominant stage (McKlin et al., 2001; Vaughan & Garrison, 2005). This variation in achievement may be caused by several factors, such as the complexity of the problem, learners' inquiry preparedness, as well as the intensity of teaching presence and social presence as enabling aspects of the progression throughout the inquiry stages (Garrison, 2016). In this study, learners in both groups put more focus on integrating ideas to answer the triggering event, albeit with a different pattern and productivity. Furthermore, the finding suggests that the KBCM group significantly showed more productive integration compared to the summary writing group.

Finding (b) indicates that the learners in the summary writing group did not spend time to understand what the given problem is and what the expected solutions are. There was a tendency to jump to a final conclusion regarding the given problem without even reflecting and confirming first what the question was about. This phenomenon is detrimental to the knowledge-building in the CoI because it risks unresolved misconceptions during the discussion if they do not show considerable effort in debating the proposed solutions later during the discussion. Some prior studies also reported a relatively low frequency of triggering event messages in online discussions (McKlin et al., 2001; Vaughan & Garrison, 2005).

In contrast to the summary writing group, the KBCM group showed some triggering event messages. This is an indication that they spent some time trying to understand the triggering question, confirm it, and show their sense of puzzlement. This may indicate an effective inquiry process, which always begins with questioning a problem, confirming what the problem is about, and how to solve it (see discussion on RQ2).

The significantly higher rate of triggering event, exploration, and integration messages per participant in the KBCM group indicated the potential of KBCM as a preparatory activity to enable more productive discussion in the mentioned practical inquiry stages better than summary writing. However, both the KBCM group and the summary writing group showed the same number of occurrences of resolution-related messages per participant. Thus, both are identically effective in fostering resolution to some degree. There is an indication that fostering more resolution requires more than providing content-engaging preparatory activity. As suggested in some works of literature, resolution requires higher-order thinking and creative thinking because the learners are expected to be able to apply solutions in different contexts and defend them (Garrison, 2016; Garrison et al., 2001). Some prior studies also showed that resolution was less exhibited during the inquiry (Garrison et al., 2001; McKlin et al., 2001; Pawan et al., 2003; Vaughan & Garrison, 2005).

***RQ2: To what extent did the pattern of occurrences of triggering event, exploration, integration, and resolution across the discussion period differ among the groups?***

To answer RQ2, both groups showed a different pattern of occurrences of the inquiry stages (see Table 3). The KBCM group showed more lower-level inquiry stages during the early phase of discussion (the first three days of the discussion period) and more higher-level inquiry stages during the latter phase (the last three days of the discussion period). In contrast, the summary writing group tended to jump into higher-level inquiry stages from the beginning of the discussion, especially integration, which indicates that the learners tended to present final answers and skipped clarifying the triggering question (see [b] in the previous subsection).

During the collaboration, it is necessary for the learners to focus on understanding what the problem is at the beginning of the inquiry before integrating ideas (Garrison, 2016; Vaughan & Garrison, 2005). This pattern resembles Dewey's reflective thinking, which served as the basis of the CoI framework. In reflective thinking, learners start by recognizing the problems, analyzing the problems, and finally proposing solutions (Meyer, 2019). Additionally, the sequential processes of gathering information and reaching a consensus were also suggested as the foundation of a successful problem-solving collaboration (Bridges, 1979). As shown in Table 3, the pattern that resembles reflective thinking appeared in the KBCM group, in which the learners showed a tendency to clarify the problem first (triggering event and exploration), then proceed to the analysis, and finally reach consensus (integration and resolution). Nevertheless, further analysis of the transition between the inquiry stages may be needed to uncover what kind of transitions (e.g., from integration to resolution, etc.) happened during the activity.

***The Potential Influence of KBCM and Summary Writing on Learners' Discussion***

Some characteristics of both KBCM and summary writing could contribute to the mentioned findings. In the case of KBCM, the learners have the opportunity to review learning materials aided by keywords presented as links and nodes, recognize key concepts, and reflect on their understanding when receiving immediate feedback during concept map reconstruction.

As suggested in a related prior work, such an activity could increase learners' awareness of common terms and concepts that were used throughout the discussion (Hasani et al., 2023). Due to the nature of the concept map as a pedagogical tool that represents knowledge structure as a web of interconnected concepts, it is possible to provide the commonly used terms or vocabulary to the learners (Colosimo & Fitzgibbons, 2012; Novak & Cañas, 2006). Examining a completed concept map could also prompt dialogue and debate (Baroody & Bartels, 2000). Thus, it could potentially lead to a productive discussion because using the same terms when referring to a specific object gives learners opportunities to discuss more deeply about such an object, including whether there is a difference in how the object is perceived. For example, if a difference happened, it might have triggered further inquiries.

In this study, this characteristic may have contributed to the higher amount of triggering event, exploration, and integration that was observed in the KBCM group. Moreover, this may also indicate sustained transactions of ideas. An example of this phenomenon is shown in Figure 6. A translated excerpt (originally written in Bahasa Indonesia) of a related conversation from a KBCM group and a summary writing group shows a part of a discussion on the given trigger question (TQ)—whether a 3 x 3 matrix could be seen as a vector (see Figure 6). The key concepts discussed in this excerpt include vectors, matrices, rows, columns, and the characteristics of a vector.

**Figure 6**

*An Excerpt From the First Two Days of Discussion Period*

**KBCM Group**

**Student A** Reply to: Triggering Question

"... let me explain my response. In my opinion, vector A (3 x 3) could be seen as a vector in the form of row vectors and column vectors..."

March 13, 6:06 PM ID:**KB1**

**Student B** Reply to: KB1

"...Maybe if we want to discuss whether it is a vector or not, it's better to define what a vector is. Maybe the title of the forum, GVS (general vector space), gives us a clue? From my understanding, GVS is a kind of *set of vectors* that satisfy certain characteristics, such as closed (addition/scalar multiplication). Just like what was discussed in the class and also during concept mapping, there are some characteristics, such as identity elements"

March 13, 8:51 PM ID:**KB2**

**Student B** Reply to: Triggering Question

"...Before we make a conclusion, it's better to clarify what a matrix is and how to define it. Then what is a vector? After that, we can identify the connections."

March 14, 10:39 AM ID:**KB3**

**Student C** Reply to: Triggering Question

"...A matrix is an arrangement of numbers in rows and columns, while a vector is a matrix with only one row or column..."

March 14, 10:47 AM ID:**KB4**

**Student B** Reply to: Triggering Question

"...Vector is a special form of matrix with only one row or column..."

March 14, 10:48 AM ID:**KB5**

**Student D** Reply to: Triggering Question

"...The relationship between vectors and matrices is that a matrix is a collection of vectors."

March 14, 11:08 AM ID:**KB6**

**Student B** Reply to: KB4

"... (this view) may invites a question: Is a matrix a set of row or column vectors?"

March 14, 11:17 AM ID:**KB7**

**Student B** Reply to: KB6

"... I agree..., but is it possible that a matrix has a structure consisting of only one row or column?... I think it is important to define vectors and matrices in a deeper way to prevent this kind of confusion... How should we define a vector?..."

March 14, 11:24 AM ID:**KB8**

**Summary Writing Group**

**Student 1** Reply to: Triggering Question

$A = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix}$

from that matrix, we can change it into a vector with components as follows
v = (1, 2, 3, 4, 5, 6, 7, 8, 9)
For proving it we can use 10 axioms.
$a + b = ((1 + b_1), (2 + b_2), (3 + b_3), (4 + b_4), (5 + b_5), (6 + b_6), (7 + b_7), (8 + b_3), (9 + b_9))$ With element $a + b \in R$. It is proven..."

March 13, 11:19 AM ID:**S1**

**Student 2** Reply to: Triggering Question

Vector addition has an associative characteristic.

a + (b + c) = (a + b) + c
a + (b + c) = ((1, b1 + c1), (2, b2 + c2), (3, b3 + c3), (4, b4 + c4), (5, b5 + c5), (6, b6 + c6), (7, b7 + c7), (8, b8 + c8), (9, b9 + c9))
a + (b + c) = ((1, b1 + c1), (2, b2 + c2), (3, b3 + c3), (4, b4 + c4), (5, b5 + c5), (6, b6 + c6), (7, b7 + c7), (8, b8 + c8), (9, b9 + c9))
Thereby, a + (b + c) = (a + b) + c is proven..."

March 13, 2:10 PM ID:**S2**

**Student 3** Reply to: Triggering Question

"I will try to prove the ninth axiom and the tenth axiom
9.
1u = u
1v = v
1(1, 2, 3, 4, 5, 6, 7, 8, 9) = (1, 2, 3, 4, 5, 6, 7, 8, 9)

March 14, 1:26 PM ID:**S3**

*Note*. This excerpt only shows a part of the discussion from the first two days of the discussion period. Some emphasis in the form of underlined words to show key concepts is added by the authors. The mathematical notations are presented as originally posted.

An excerpt from a KBCM group shows an example of how a group of learners who were aware of the aforementioned key concepts and the existence of relationships between them (e.g., vectors and matrices) tried to reach agreement regarding how to respond to the TQ—i.e., whether a 3 x 3 matrix is a vector—as well as agree on how a vector and a matrix could be defined, including their relationship. In the process, they were responding to each other's ideas and sharing relevant resources (including the goal map), thus increasing the occurrence of exploration and integration. In addition, the behavior of trying to understand relationships between concepts (see messages from Students A, B, C, and D in Figure 6) could also be encouraged by the use of KBCM prior to the discussion as well as reviewing the goal map during the discussion.

Regarding the possible role of KBCM in influencing the discussion, a study suggested that a well-designed concept map is an effective external representation of knowledge structure that could encourage certain cognitive behaviors more than a mere memory aid (Zhang, 1997). Thus, a concept map is worth sharing during the discussion, especially during the exploration stage. In addition, KBCM provided an advantage in the form of immediate feedback that enabled deeper reflection as well as greater awareness of the existence of relationships between key terms and concepts used in the discussion. This might have contributed to a productive inquiry, e.g., confirming understanding about such relationships when exploring possible solutions (for example, see Student B's messages in Figure 6).

As a result of this productive inquiry, the learners could have more opportunity to reflect on their understanding as well as the others' (e.g., by revisiting posts and the concept map), thus learning more deeply about the topic. Such a personal reflection is an activity that affects cognitive presence and critical thinking (Koehler et al., 2020; Maranna et al., 2022); thus, it may explain the finding of a higher number of cognitive presence messages in the KBCM group, especially the rate of messages indicating integration. In addition, they may also detect their own misconceptions in the process, which is one of the requirements of the context of learning in this case—revising misconceptions about vectors.

In the case of the summary writing group, writing a summary was shown to have less effectiveness for increasing discussion productivity due to some possible factors. Firstly, learners might have written summaries with different content and scope, even though they were provided with the same learning materials and guided with subtopics; thus, they may have difficulties recognizing relationships between key concepts. Secondly, without receiving immediate feedback when writing a propositional sentence, they may have used different words for describing key concepts (e.g., vectors and matrices) and retained misconceptions throughout the whole activity, even though they were provided with the teacher-created summary as the feedback that is accessible during the discussion. These factors might have caused them to be less aware of the key concepts and encouraged a "jumping to solutions" kind of discussion in the summary writing group. An example of this case is shown in the excerpt from a summary writing group—note that the responses tend to directly answer the TQ or add to prior messages to directly present the solution. This phenomenon showed some similarity to the one reported in prior works on asynchronous discussion that showed some learners' tendency to scratch only the surface of the problems and do the bare minimums, e.g., respond only for the sake of being there, in order to satisfy the course's requirements (Hara et al., 2000; Koehler et al., 2020).

In this case, the students tend to present the final answer to the proof even at the beginning of the discussion, albeit in an invalid way. Two errors remained unresolved in the discussion, which include insufficient proof by example (see messages from Students 1, 2 and 3 in Figure 6) and a howler for transforming elements of a 3 x 3 matrix into a 9-dimensional vector (see Student 1's message in Figure 6). This phenomenon may indicate the tendency of novice learners of mathematics to rely on mere memorization of formulas or principles without trying to understand the connection between the concepts that have been taught and the problems they encounter (Hafiz et al., 2017).

These cases are examples of how the difference in the form of preparatory activity and knowledge representation used as the reference for the discussion could lead to a different pattern of discussion. Nevertheless, these cases cannot be generalized yet and require further investigation due to the possibility of influences from other factors existing in real-classroom settings, such as motivations, attitudes towards OCL, etc.

***Practical Implications and Recommendations***

In the case of achieving deeper learning as the learning goal in online collaborative learning, learners are expected to create knowledge and reflect on their understanding through performing collaborative tasks (e.g., asynchronous online discussion) and achieve higher-level inquiry stages for effective learning (Koszalka et al., 2021; Villanueva et al., 2022). In the general context of improving online collaborative learning delivery, the following measures may help learners succeed in achieving the mentioned expectations:

(a) providing an activity of organizing information as a complementary activity during the pre-discussion training to prepare the learners to productively contribute to the discourse
(b) KBCM or similar activities may be provided
(c) a teacher-created concept map may be provided throughout the discussion as a reference for the learners to discuss

Providing an online asynchronous forum as a mere learning environment does not necessarily lead to a productive discussion with high-level inquiry (Moore & Miller, 2022; Sadaf & Olesova, 2017). Moreover, a productive discussion does not necessarily include higher-level critical thinking because of the possibility for the learners to show surface-level thinking and exhibit a bare minimum, such as echoing responses in the discussion, as reported in some studies (Essa et al., 2023; Hara et al., 2000; Hsiao et al., 2013; Koehler et al., 2020). As a result, some strategies are needed, such as providing facilitation (An et al., 2009; Chen et al., 2019) and providing learning analytics to monitor discussion (Alwafi, 2022)—each of which comes with some advantages and limitations. Alternatively, a content-engaging preparatory activity may be provided as a complement to the existing strategies to prepare the learners before the discussion. As suggested by Saadatmand et al. (2017), providing a content-engaging activity may foster learners' cognitive presence and critical thinking through personal reflection (Maranna et al., 2022). This study provides evidence of the potential of KBCM as a better alternative to summary writing for preparing learners to achieve higher-level inquiry in an asynchronous discussion based on the CoI framework.

In particular, this study also contributed to addressing the question of how to improve the collaborative learning of mathematics in a higher-education context. In such a context, critical thinking in the sense of evaluating personal understanding as well as others' ability to make informed decisions is one of the important aspects that is expected to be acquired by learners (Ernest, 2010; Sachdeva & Eggen, 2021). Achieving higher-level thinking through performing the higher-level inquiry stages (integration and resolution) is necessary to move from surface learning to deeper learning about the concepts in a mathematics subject. Doing the bare minimum or addressing only the surface of the problems, as reported in some OCL implementations in the past (Hara et al., 2000; Koehler et al., 2020), is insufficient for gaining a correct and complete understanding of a topic in a mathematics subject, e.g., linear algebra. The results suggested that KBCM followed by a CoI-based online asynchronous discussion has the potential to be an alternative for helping learners achieve the expected higher-level thinking about a topic in mathematics.

Several issues could be explored further, such as finding effective ways for encouraging learners to achieve resolution; comparing KBCM with other forms of OCL preparatory activities; and applying the proposed activity in different educational contexts. Regarding achieving resolution, it remains a challenging part due to the complexity of preparing the learners to conduct higher-order thinking during the discussion as well as creative thinking to enable "out of the box" ideas to appear when trying to apply the proposed solution in other contexts.

# Conclusion

In some learning contexts, ensuring the achievement of higher-level inquiry stages is difficult using facilitation and preparatory activities involving discussion training and reviews of learning materials through writing a summary. Concept mapping is a promising way to help learners become aware of important concepts and terms related to the discussion and could be used in a preparatory activity before a discussion. However, using traditional scratch concept mapping may be unfit for all types of learners (e.g., low achievers), as they may have difficulties in making correct propositions. Kit-build concept mapping (KBCM) could be a solution that is fit for all types of learners due to providing components to be used for reconstrcuting a teacher-created map, which could help all types of learners become aware of the concepts. This study presents evidence regarding the potential of using KBCM as a better preparatory activity to support cognitive presence in an online discussion up to the integration stage, compared to summary writing.

RQ1: To what extent did the number of messages categorized as triggering event, exploration, integration, and resolution differ among the groups? The results show that learners in the KBCM group exhibited a significantly higher rate of message occurrences for triggering event, exploration, and integration compared to the summary writing group.

RQ2: To what extent did the pattern of occurrences of triggering event, exploration, integration, and resolution across the discussion period differ among the groups? The KBCM group tended to focus on triggering event and exploration at the beginning, followed by integration and resolution at the end, while the summary writing group tended to focus only on integration throughout the discussion.

In addition, there is evidence that indicates opportunities for more transactions of ideas necessary for deeper learning and revising misconceptions. Some possible influential factors resulting from KBCM activity include increased awareness of key concepts, terms, and the relationship between concepts included in the basic knowledge related to the discussion topic, which may be harder to achieve by writing a summary. Nevertheless, such an effect needs to be confirmed in future studies due to the limitations of implementing the treatments in linear algebra classes as a case study. Thus, the results cannot be generalized yet. This study contributes to the state-of-the-art of OCL by providing an alternative preparatory method for fostering higher-level inquiry stages in online discussion. Future studies need to investigate whether such treatments are effective for different topics or subjects. Additionally, future studies involving a larger number of participants and a better controlled sample are needed to investigate whether the results could be replicated.

## Acknowledgements

This work was supported by JSPS KAKENHI Grant Number 19K12269. The KBCM system used in this study was developed by Aryo Pinandito, PhD, and is under the joint management of Brawijaya University and Hiroshima University.

## Declarations

This study has received ethical clearance and has been approved by the teaching team of the involved classes. Due to the fact that the institutional board had not yet been formed when this study was being conducted, the university has provided a formal assertion that the authors of this study had obtained participants' informed consent prior to the experiment (Reference Letter No. S- 3 /UN2.F11.D1.5/PPM.00.00/2024). The authors declare no conflict of interest in this study.

# References


Alwafi, E. (2022). Designing an online discussion strategy with learning analytics feedback on the level of cognitive presence and student interaction in an online learning community. *Online Learning*, *26*(1), 80–92. https://doi.org/10.24059/olj.v26i1.3065

An, H., Shin, S., & Lim, K. (2009). The effects of different instructor facilitation approaches on students' interactions during asynchronous online discussions. *Computers & Education*, *53*(3), 749–760. https://doi.org/10.1016/j.compedu.2009.04.015

Baroody, A. J., & Bartels, B. H. (2000). Using concept maps to link mathematical ideas. *Mathematics Teaching in the Middle School*, *5*(9), 604–609. http://cunycci.pbworks.com/w/file/fetch/81999935/concept%20maps.pdf

Bates, A. W. (2022). *Teaching in a digital age: Guidelines for designing teaching and learning* (3rd ed.). Tony Bates Associates Ltd.

Bradley, M. E., Thom, L. R., Hayes, J., & Hay, C. (2008). Ask and you will receive: how question type influences quantity and quality of online discussions. *British Journal of Educational Technology*, *39*(5), 888–900. https://doi.org/10.1111/j.1467-8535.2007.00804.x

Bridges, D. (1979). *Education, democracy and discussion*. NFER Publishing .

Campbell, J. L., Quincy, C., Osserman, J., & Pedersen, O. K. (2013). Coding in-depth semi structured interviews. *Sociological Methods & Research*, *42*(3), 294–320. https://doi.org/10.1177/0049124113500475

Chen, Y., Lei, J., & Cheng, J. (2019). What if online students take on the responsibility: Students' cognitive presence and peer facilitation techniques. *Online Learning Journal*, *23*(1), 37–61. https://doi.org/10.24059/olj.v23i1.1348

Colosimo, A., & Fitzgibbons, M. (2012). Teaching, designing, and organizing: Concept mapping for librarians. *Partnership: The Canadian Journal of Library and Information Practice and Research*, *7*(1). https://doi.org/10.21083/partnership.v7i1.1800

Ernest, P. (2010). The scope and limits of critical mathematics education. In *Critical Mathematics Education: Past, Present and Future* (pp. 65–87). BRILL. https://doi.org/10.1163/9789460911644_007

Essa, F. V., Andrews, G., Mendelowitz, B., Reed, Y., & Fouche, I. (2023). Humanising Online Pedagogy through Asynchronous Discussion Forums. *Online Learning*, *27*(4), 508–529. https://doi.org/10.24059/olj.v27i4.3652

Fung, Y. Y. H. (2004). Collaborative online learning: Interaction patterns and limiting factors. *Open Learning: The Journal of Open, Distance and e-Learning*, *19*(2), 135–149. https://doi.org/10.1080/0268051042000224743

Garrison, D. R. (2016). *Thinking collaboratively: Learning in a Community of Inquiry*. Routledge.

Garrison, D. R., Anderson, T., & Archer, W. (1999). Critical inquiry in a text-based environment: Computer conferencing in higher education. *The Internet and Higher Education*, *2*(2–3), 87–105. https://doi.org/10.1016/S1096-7516(00)00016-6

Garrison, D. R., Anderson, T., & Archer, W. (2001). Critical thinking, cognitive presence, and computer conferencing in distance education. *American Journal of Distance Education*, *15*(1), 7–23. https://doi.org/10.1080/08923640109527071

Garrison, D. R., & Cleveland-Innes, M. (2005). Facilitating cognitive presence in online learning: Interaction is not enough. *American Journal of Distance Education*, *19*(3), 133–148. https://doi.org/10.1207/s15389286ajde1903_2

Hafiz, M., Kadir, & Fatra, M. (2017). Concept mapping learning strategy to enhance students' mathematical connection ability. *Proceedings of the 3rd International Seminar on Mathematics, Science, and Computer Science Education*. https://doi.org/10.1063/1.4983944

Hara, N., Bonk, C. J., & Angeli, C. (2000). Content analysis of online discussion in an applied educational. *Instructional Science*, *28*(2), 115–152. https://doi.org/10.1023/A:1003764722829

Harasim, L. (2017). *Learning theory and online technologies* (2nd ed.). Routledge.

Hasani, L. M., Junus, K., Sadita, L., Hirashima, T., & Hayashi, Y. (2023). A preliminary study on knowledge reconstruction activity for fostering cognitive presence in online discussion. In J. L. Shih, A. Kashihara, W. Chen, & H. Ogata (Eds.), *Proceedings of the 31st International Conference on Computers in Education* (pp. 475–484). Asia-Pacific Society for Computers in Education. https://doi.org/10.58459/icce.2023.1426

Hirashima, T., Yamasaki, K., Fukuda, H., & Funaoi, H. (2011). Kit-build concept map for automatic diagnosis. In G. Biswas, S. Bull, J. Kay, & A. Mitrovic (Eds.), *Artificial Intelligence in Education (AIED 2011)* (pp. 466–468). Springer. https://doi.org/10.1007/978-3-642-21869-9_71

Hsiao, W.-Y., Chen, M. W., & Hu, H.-W. (2013). Assessing online discussion: Adoption of critical thinking as a grading criterion. *The International Journal of Technology, Knowledge, and Society*, *9*(3), 15–25. https://doi.org/10.18848/1832-3669/CGP/v09i03/56370

Junus, K. (2023). *Pembelajaran kolaboratif daring asinkron*. UI Publishing.

Junus, K., Suhartanto, H., Suradijono, S. H. R., Santoso, H. B., & Sadita, L. (2019). The community of inquiry model training using the cognitive apprenticeship approach to improve students' learning strategy in the asynchronous discussion forum. *Journal of Educators Online*, *16*(1). https://doi.org/10.9743/jeo.2019.16.1.7

Koehler, A. A., Cheng, Z., Fiock, H., Janakiraman, S., & Wang, H. (2020). Asynchronous online discussions during case-based learning: A problem-solving process. *Online Learning*, *24*(4), 64–92. https://doi.org/10.24059/olj.v24i4.2332

Koszalka, T. A., Pavlov, Y., & Wu, Y. (2021). The informed use of pre-work activities in collaborative asynchronous online discussions: The exploration of idea exchange, content focus, and deep learning. *Computers & Education*, *161*. https://doi.org/10.1016/j.compedu.2020.104067

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, *33*(1), 159–174. https://doi.org/10.2307/2529310

Lee, J., Soleimani, F., Irish, I., Hosmer, I. J., Soylu, M. Y., Finkelberg, R., & Chatterjee, S. (2022). Predicting cognitive presence in at-scale online learning: MOOC and for-credit online course environments. *Online Learning*, *26*(1), 58–79. https://doi.org/10.24059/olj.v26i1.3060

Maranna, S., Willison, J., Joksimovic, S., Parange, N., & Costabile, M. (2022). Factors that influence cognitive presence: A scoping review. *Australasian Journal of Educational Technology*, *38*(4), 95–111. https://doi.org/10.14742/ajet.7878

McCarron, G. P., Olesova, L., & Calkins, B. (2021). An exploratory examination of student-led, asynchronous collaborative online discussions in fostering higher-order cognitive skills and ethical leadership learning. *Online Learning*, *25*(4), 198–219. https://doi.org/10.24059/olj.v25i4.2895

McKlin, T., Harmon, S. W., Evans, W., & Jones, M. G. (2001). Cognitive presence in web-based learning: A content analysis of students' online discussions. *Annual Proceedings of Selected Research and Development and Practice Papers Presented at the National Convention of the Association for Educational Communications and Technology*, 272–277. https://files.eric.ed.gov/fulltext/ED470101.pdf

Mende, S., Proske, A., & Narciss, S. (2021). Individual preparation for collaborative learning: Systematic review and synthesis. *Educational Psychologist*, *56*(1), 29–53. https://doi.org/10.1080/00461520.2020.1828086

Meyer, K. A. (2019). The ebb and flow of online discussions: What Bloom can tell us about our students' conversations. *Online Learning*, *9*(1), 53–63. https://doi.org/10.24059/olj.v9i1.1802

Moore, R. L., & Miller, C. N. (2022). Fostering cognitive presence in online courses: A systematic review (2008-2020). *Online Learning Journal*, *26*(1), 130–149. https://doi.org/10.24059/olj.v26i1.3071

Novak, J. D., & Cañas, A. J. (2006). *The theory underlying concept maps and how to construct them*. https://cmap.ihmc.us/publications/researchpapers/theorycmaps/theoryunderlyingconceptmaps.bck-11-01-06.htm

Nurmaya, Pinandito, A., Hayashi, Y., & Hirashima, T. (2023a). Investigation of the relationship between map quality and higher-order thinking in kit-build concept map. In H., Mori & Y. Asahi (Eds.), *Human Interface and the Management of Information. HCII 2023. Lecture Notes in Computer Science* (pp. 363–377). https://doi.org/10.1007/978-3-031-35129-7_27

Nurmaya, Pinandito, A., Hayashi, Y., & Hirashima, T. (2023b). Promoting students' higher order thinking with concept map recomposition. *IEICE Transactions on Information and Systems*, *E106.D*(8), 2022EDP7203. https://doi.org/10.1587/transinf.2022EDP7203

Olesova, L., Sadaf, A., Kumar, S., Ozogul, G., Zhu, M., Moore, R. L., Miller, C., & Phillips, T. M. (2022). Cognitive presence in online courses: design and facilitation of collaborative learning. In M. Simonson & D. Seepersaud (Eds.), *2022 AECT Convention Proceedings Vol. 2: Practice of Educational Communications and Technology* (pp. 684–693). https://members.aect.org/pdf/Proceedings/proceedings22/2022i/22_23.pdf

Oyarzun, B., & Martin, F. (2023). A systematic review of research on online learner collaboration from 2012–21: Collaboration technologies, design, facilitation, and outcomes. *Online Learning*, *27*(1), 71–106. https://doi.org/10.24059/olj.v27i1.3407

Park, H., & Shea, P. (2020). A ten-year review of online learning research through co-citation analysis. *Online Learning*, *24*(2), 225–244. https://doi.org/10.24059/olj.v24i2.2001

Pawan, F., Paulus, T. M., Yalcin, S., & Chang, C. F. (2003). Online learning: Patterns of engagement and interaction among in-service teachers. *Language Learning & Technology*, *7*(3), 119–140. https://scholarspace.manoa.hawaii.edu/server/api/core/bitstreams/adeb2944-20ed-4f3f-ba39-5cc72a8d0a45/content

Pinandito, A., Prasetya, D. D., Az-Zahra, M., Hayashi, Y., & Hirashima, T. (2021). Preliminary review of online collaborative kit-build concept map tool in practical use. *Proceedings of the Business Innovation and Engineering Conference 2020 (BIEC 2020)*, 46–53. https://doi.org/https://doi.org/10.2991/aebmr.k.210727.009

Rourke, L., & Kanuka, H. (2009). Learning in communities of inquiry: A review of the literature. *International Journal of E-Learning & Distance Education*, *23*(1), 19–48. https://www.ijede.ca/index.php/jde/article/view/474/875

Saadatmand, M., Uhlin, L., Hedberg, M., Åbjörnsson, L., & Kvarnström, M. (2017). Examining learners' interaction in an open online course through the community of inquiry framework. *European Journal of Open, Distance and E-Learning*, *20*(1), 61–79. https://doi.org/10.1515/eurodl-2017-0004

Sachdeva, S., & Eggen, P.-O. (2021). Learners' critical thinking about learning mathematics. *International Electronic Journal of Mathematics Education*, *16*(3), em0644. https://doi.org/10.29333/iejme/11003

Sadaf, A., & Olesova, L. (2017). Enhancing cognitive presence in online case discussions with questions based on the practical inquiry model. *American Journal of Distance Education*, *31*(1), 56–69. https://doi.org/10.1080/08923647.2017.1267525

Shea, P., Hayes, S., Vickers, J., Gozza-Cohen, M., Uzuner, S., Mehta, R., Valchova, A., & Rangan, P. (2010). A re-examination of the community of inquiry framework: Social network and content analysis. *Internet and Higher Education*, *13*(1–2), 10–21. https://doi.org/10.1016/j.iheduc.2009.11.002

Valverde-Berrocoso, J., Garrido-Arroyo, M. del C., Burgos-Videla, C., & Morales-Cevallos, M. B. (2020). Trends in educational research about e-Learning: A systematic literature review (2009–2018). *Sustainability*, *12*(12), 5153. https://doi.org/10.3390/su12125153

Vaughan, N., & Garrison, D. R. (2005). Creating cognitive presence in a blended faculty development community. *The Internet and Higher Education*, *8*(1), 1–12. https://doi.org/10.1016/j.iheduc.2004.11.001

Villanueva, J. A. R., Redmond, P., & Galligan, L. (2022). Manifestations of cognitive presence in blended learning classes of the Philippine K-12 system. *Online Learning*, *26*(1), 19–37. https://doi.org/10.24059/olj.v26i1.3021

Weinberger, A., Ertl, B., Fischer, F., & Mandl, H. (2005). Epistemic and social scripts in computer-supported collaborative learning. *Instructional Science*, *33*(1), 1–30. https://doi.org/10.1007/s11251-004-2322-4

Yamasaki, K., Fukuda, H., Hirashima, T., & Funaoi, H. (2010). Kit-build concept map and its preliminary evaluation. *Proceedings of The 18th International Conference on Computers in Education* (pp. 290–294). https://doi.org/10.58459/icce.2010.87

Zhang, J. (1997). The nature of external representations in problem solving. *Cognitive Science*, *21*(2), 179–217. https://doi.org/10.1207/s15516709cog2102_3