Improving Community of Inquiry-Based Asynchronous Online Discussion through Improving Conceptual Knowledge by Information-Organizing Preparatory Activity with Kit-Build Concept Mapping

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Abstract

Online discussion based on the community of inquiry (CoI) framework has received considerable popularity due to its potential benefits for enhancing problem-solving skills and achieving deep understanding in the long term. However, it is challenging to make learners actively conduct a discussion using typical environments (e.g., asynchronous online forums). Information-organizing activity (IOA) has been proposed as one of the preparatory activities for preparing learners to actively discuss topics. Compared to the typical structured summary writing (SW), kit-build concept mapping (KBCM) has been proposed in past studies as an alternative IOA with the potential of fostering more cognitive presence and higher-level inquiry messages. However, such potentials were yet to be confirmed by a comparative study with a balanced sample size. Additionally, conceptual knowledge was hypothesized as influential in affecting learners' inquiry. This follow-up study aims to confirm the potential of KBCM as an alternative IOA for achieving better discussion. Moreover, this study contributes to investigating the relationship between conceptual knowledge and inquiry stages performed by learners to explain the effect of KBCM. By analyzing the discussion transcripts of 75 undergraduate computer science students from a public university who engaged in CoI-based discussions on linear algebra, this study found further evidence that KBCM is effective for fostering exploration, the evidence that a higher conceptual knowledge level after KBCM contributed to more exploration, and a tendency to perform integration→exploration and integration→resolution transitions among KBCM learners.

Keywords: Community of inquiry, online discussion, conceptual knowledge, information-organizing activity, kit-build concept map, summary

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Introduction

Asynchronous online discussions have been adopted in educational contexts due to their potential to encourage critical thinking and deeper learning (Garrison, 2016; Garrison et al., 2003). Deepening understanding of a learning content is one of the potential benefits of asynchronous online discussions (Torres & Satti, 2024). However, despite its potential, providing an online discussion can be effective only if the participants actively contribute to the inquiry (Gasmi, 2022; Swan et al., 2000; Yang et al., 2007). Low participation and shallow discussions have been reported as issues that persist in many online discussions, which may hinder learners from gaining the potential benefits of online discussion (Fung, 2004; Garrison & Cleveland-Innes, 2005; Hew et al., 2010; Mazzolini & Maddison, 2003; Pawan et al., 2003). Such issues lead to the need for learning environments and activities that encourage active participation.

One of the frameworks that have been widely adopted to design and implement asynchronous online discussions (e.g., online forums, social media, etc.) is the community of inquiry (CoI) framework (Garrison et al., 1999; Popescu & Badea, 2020; Valverde-Berrocoso et al., 2020). The CoI framework describes how three presences (i.e., cognitive, social, and teaching) are needed to achieve a meaningful learning experience through problem-solving and inquiry (Garrison, 2016). Cognitive, social, and teaching presence focus on the process of learning, facilitation of the inquiry, and facilitation of collaboration among the participants, respectively (Sadaf et al., 2021).

Cognitive presence is operationalized by four inquiry stages that learners need to perform: triggering event, exploration, integration, and resolution (Garrison et al., 1999). During the triggering event, learners try to understand the problem and how to engage with it. In the exploration stage, they explore possible solutions and share relevant resources to work on. In the integration stage, they elaborate ideas into a coherent solution or conclusion. Finally, if they can think more critically, they may try to defend the solution, show its application in different contexts, and reach resolution. Cognitive presence is one of the elements that determine the quality of the discussion (Garrison, 2017). A high number of messages indicating the inquiry stages being performed (triggering event, exploration, integration, and resolution) may characterize a successful discussion because cognitive presence is central to the success of learning activity and influences learning outcomes (Akyol & Garrison, 2011; R. L. Moore &

Miller, 2022). Experiencing a meaningful discussion fosters necessary collaborative skills to develop deep understanding (Torres & Satti, 2024).

However, research suggests that it is challenging for online discussions to go through all stages of inquiry (Garrison & Arbaugh, 2007; Rourke & Kanuka, 2009). Merely providing an online discussion forum does not result in a high amount of cognitive presence (Garrison et al., 2001; R. L. Moore & Miller, 2022). Regarding this issue, many factors may affect the learners' cognitive presence during online discussions, such as the awareness of commonly referred terms and concepts within the discussion topic, i.e., familiarity and fluency in using relevant terms during the discussion (Hasani et al., 2023). Learners' conceptual knowledge, especially the basic knowledge related to the topics (e.g., how relevant concepts are interrelated), may play a role in influencing their interactions in the discussion. Several past studies emphasized the importance of conceptual knowledge for solving problems (Bereiter, 2014; Braithwaite & Sprague, 2021; Cracolice et al., 2008; Surif et al., 2012). Thus, having sufficient and well-organized basic conceptual knowledge related to a discussion is an important prerequisite for engaging in an effective and meaningful problem-solving discussion.

Nevertheless, most learners usually lack conceptual understanding (Surif et al., 2012). Some studies suggested that learners, in particular novice learners, may experience difficulty in conducting a deep discussion about a topic due to their unfamiliarity with the terms and concepts within the relevant basic knowledge, inability to facilitate discussion effectively, heavy reliance on recalling facts, and tendency to follow rules without reasoned judgments (Persky & Robinson, 2017; Weinberger et al., 2005). Unfamiliarity with the terms used in the knowledge domain among novice learners may also hinder them from solving problems effectively (Martin & Evans, 2018).

To prepare learners, especially novice learners, to engage in an effective problem-solving discussion, preparatory activities that focus on training the learners on how to elaborate and express ideas may be provided before the discussion (Junus et al., 2019; Sadita et al., 2020). A prior study suggested that increasing engagement with the learning content, e.g., the materials related to the discussion topic, may increase the quality of the discussion (Saadatmand et al., 2017).

Information-organizing activity (IOA) is one of the alternatives for increasing engagement with the discussion-related topics and preparing the learners to conduct a good CoI discussion by making them aware of the terms and concepts related to the topics as well as having a well-organized understanding of the topics, i.e., aware of the relationships between important concepts. A well-organized understanding is one of the characteristics of an expert knowledge base and one of the prerequisites of meaningful learning (Kalyuga, 2007; Novak & Cañas, 2006); thus, having one may help solve problems or engage in an inquiry about a particular topic.

IOA can be done by writing a summary of the learning materials, which is an activity that has been widely integrated as a part of the instruction in many educational contexts. In summary writing, learners are expected to select important concepts and organize them into coherent propositions through paraphrases (Pilegard & Fiorella, 2016). Another alternative is making a concept map from scratch (scratch concept mapping/SCM), which involves a visual representation of knowledge structure (Novak & Cañas, 2006). In SCM, learners extract propositions from learning materials and express them in concept-link-concept structures. Both alternatives require learners to extract and express the knowledge structure in the form of propositions, in complete sentences within a summary or concept-link-concept visually represented as nodes and links in a concept map.

Nevertheless, both summary writing and SCM may be difficult for novice learners because both activities require them to extract the knowledge structure by themselves, which poses a high cognitive load (Hasani et al., 2023). There is a possibility that learners might produce a low-quality representation of the knowledge structure, e.g., incorrect terms, incorrect propositions, etc. In the case of summary writing, the learners may experience difficulties in selecting important ideas from the materials and do not wish to exert sufficient efforts due to a high cognitive load and end up copying and pasting verbatim sentences for writing their summary, which is detrimental to their effort in achieving well-organized knowledge (Chuenchaichon, 2022; Pilegard & Fiorella, 2016; Spirgel & Delaney, 2016).

To address this issue, another alternative called kit-build concept mapping (KBCM) may be implemented. In KBCM, learners reconstruct teacher-created maps from components and receive immediate feedback during the attempt (Hirashima et al., 2011; Yamasaki et al., 2010). This may help learners catch the knowledge structure and confirm their understanding. It may also help them develop a well-organized understanding of the discussion topic without making them extract the structure of the knowledge domain from zero, i.e., reducing their cognitive load.

Related prior studies showed that KBCM *has the potential* to be better than summary writing in fostering cognitive presence, which includes triggering event, exploration, and integration, and to follow transitions that resemble a scientific inquiry process: triggering event-exploration-integration (Hasani et al., 2023; Hasani, Junus, Sadita, Ayano, et al., 2025; Hasani, Junus, Sadita, Hirashima, et al., 2025). However, the previously mentioned related studies were limited by an unbalanced sample size, making it difficult to generalize the results. In addition, despite prior studies suggesting that having conceptual knowledge is important for effective problem-solving (e.g., Braithwaite & Sprague, 2021; Surif et al., 2012), there is a lack of studies that investigate its role in shaping learners' behavior in a problem-solving discussion. In other words, whether the conceptual knowledge about the discussion-related topics affects learners' cognitive presence during the discussion is not well understood.

Therefore, a follow-up study involving a balanced sample size is needed to *confirm* the effectiveness of KBCM for fostering the inquiry stages in online discussion and *investigate* the role of learners' conceptual understanding. This study provides further evidence of KBCM's effect as pre-discussion IOA and proposes KBCM as an alternative IOA. This study aims to realize a better CoI-based discussion experience for learners by answering the following research questions.

- (RQ1) To what extent did the occurrence of inquiry stages in the discussion differ?
- (RQ2) To what extent did the pattern of transitions between inquiry stages in the discussion differ?

- (RQ3) Is there a relationship between the learners' conceptual understanding after the treatment and the occurrence of each inquiry stage in the discussion?

RQ1 and RQ2 are posed to confirm, under a balanced sample size, whether KBCM could be the better alternative for: (a) fostering one or more inquiry stages compared to the traditional summary writing method (e.g., through calculating the rate of messages containing an inquiry stage) and (b) encouraging learners to perform transitions between inquiry stages that resemble a scientific inquiry (triggering event-exploration-integration-resolution); thus, informing teachers regarding further evidence of KBCM's effectiveness as pre-discussion IOA and regarding some practical implications on the use of KBCM. RQ3 is posed to investigate whether learners' conceptual understanding after the treatment is related to the learners' discussion performance in showing the inquiry stages (e.g., by performing correlation analysis involving conceptual knowledge test score after the treatment and the type of the treatment); thus, explaining the effect of KBCM on the discussion process.

Theoretical Framework

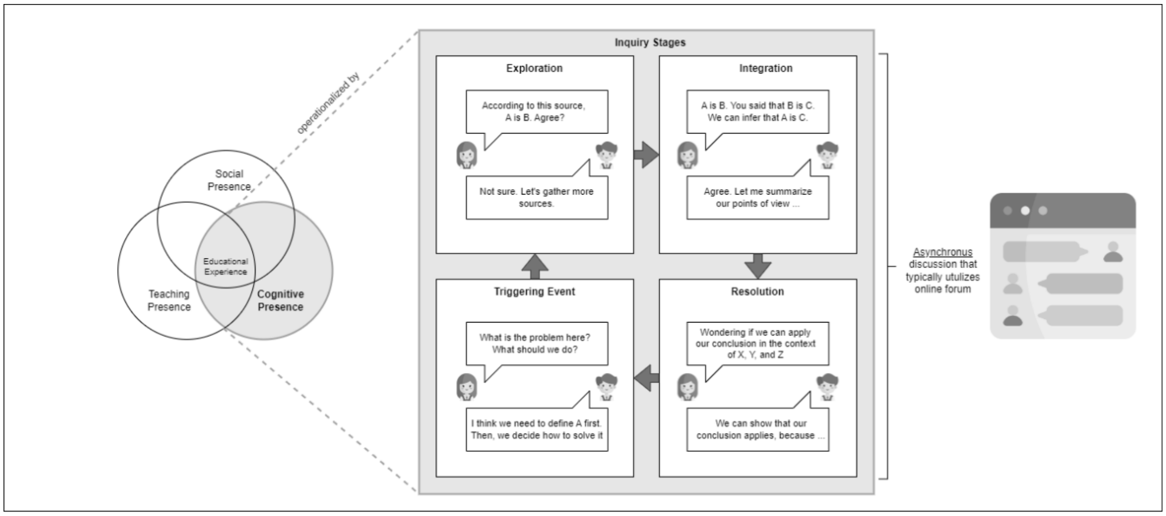
Community of Inquiry Framework for Meaningful Collaborative Learning

The CoI framework defines three presences that make up meaningful educational experience within the mentioned community of inquiry in a collaborative learning environment: social, cognitive, and teaching presence (Garrison et al., 1999). Social presence refers to the ability of the participants in the CoI to project their individual personalities through the medium of communication being used (Garrison et al., 1999). Cognitive presence is the extent of the learners' ability to construct and confirm meaning through active participation in the transaction of ideas (Garrison et al., 2001). Teaching presence, on the other hand, refers to the design, facilitation, and direction of social and cognitive processes within the collaborative learning activity to achieve its educational goals (Garrison et al., 2001).

In addition, the practical inquiry model further describes four inquiry stages that operationalize cognitive presence in the community of inquiry: triggering event, exploration, integration, and resolution (Garrison et al., 2001). Figure 1 illustrates how inquiry stages could be performed by a community of inquiry in an asynchronous online discussion forum.

Figure 1

The Community of Inquiry Framework and the Practical Inquiry Model



Note. This figure is designed using images made by Freepik from Flaticon (https://flaticon.com).
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Information-Organizing Activities as Discussion Preparatory Activity

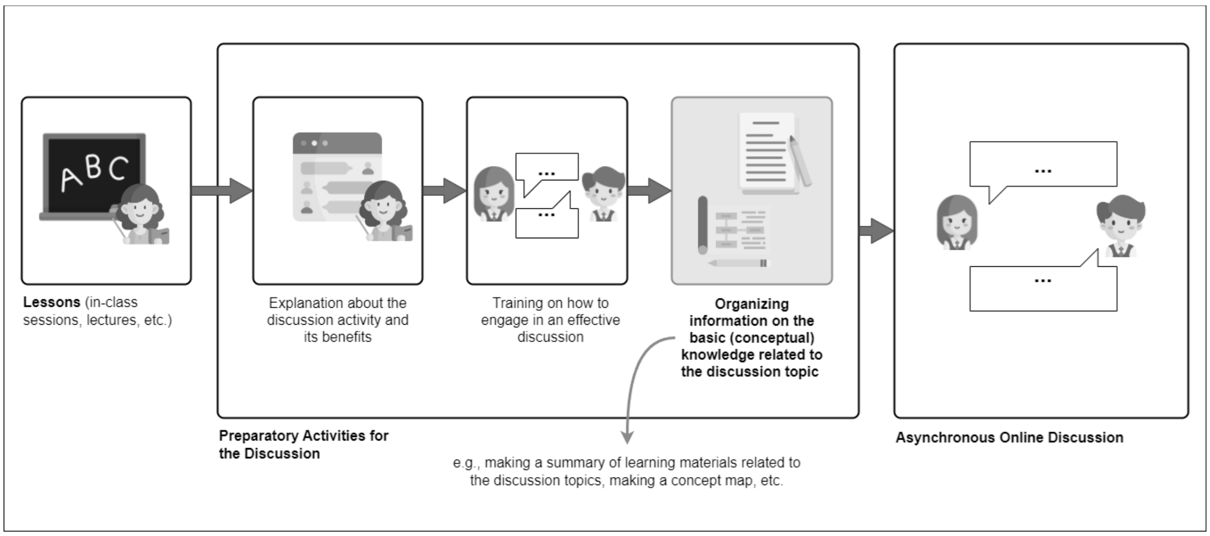
A number of studies suggested the importance of conceptual knowledge in addition to procedural knowledge for problem solving across educational contexts (Bereiter, 2014; Braithwaite & Sprague, 2021; Cracolice et al., 2008; Surif et al., 2012). Possessing a well-organized understanding about the conceptual knowledge related to the discussion topics may help learners to conduct an effective and productive inquiry in addition to achieving a more refined conceptual understanding throughout the activity.

The activity of organizing information (e.g., writing a summary or making concept maps) has been integrated into instructions in many educational contexts to help learners retain information, improve critical comprehension of text material, and achieve meaningful learning (Novak & Cañas, 2006; Shokrpour et al., 2013; Spirgel & Delaney, 2016). Additionally, achieving meaningful learning requires well-organized knowledge structure and commitment to integrate with existing knowledge (Novak & Cañas, 2006).

A prior study suggested that activities that increase learners' engagement with content of the discussion topics may be provided to improve their discussion (Saadatmand et al., 2017). As a form of content-engaging activity, the activity of organizing information can be provided prior to the discussion activity in addition to other necessary preparations (see Figure 2). Prior studies suggested the importance of providing discussion guides and training on how to engage meaningfully in a discussion (Junus et al., 2019; Sadita et al., 2020). By adding information-organizing activities in complement to the mentioned preparatory activities, learners are expected to organize information related to discussion topics, such as general facts or principles related to the problems or procedures for solving the problems that will be focused in the discussion later on.

Figure 2

Information-Organizing Activities as One of the Preparatory Activities for Engaging in Collaborative Learning



Note. This figure is designed using images made by Mihimihi, Freepik, and justicon from Flaticon (https://flaticon.com).

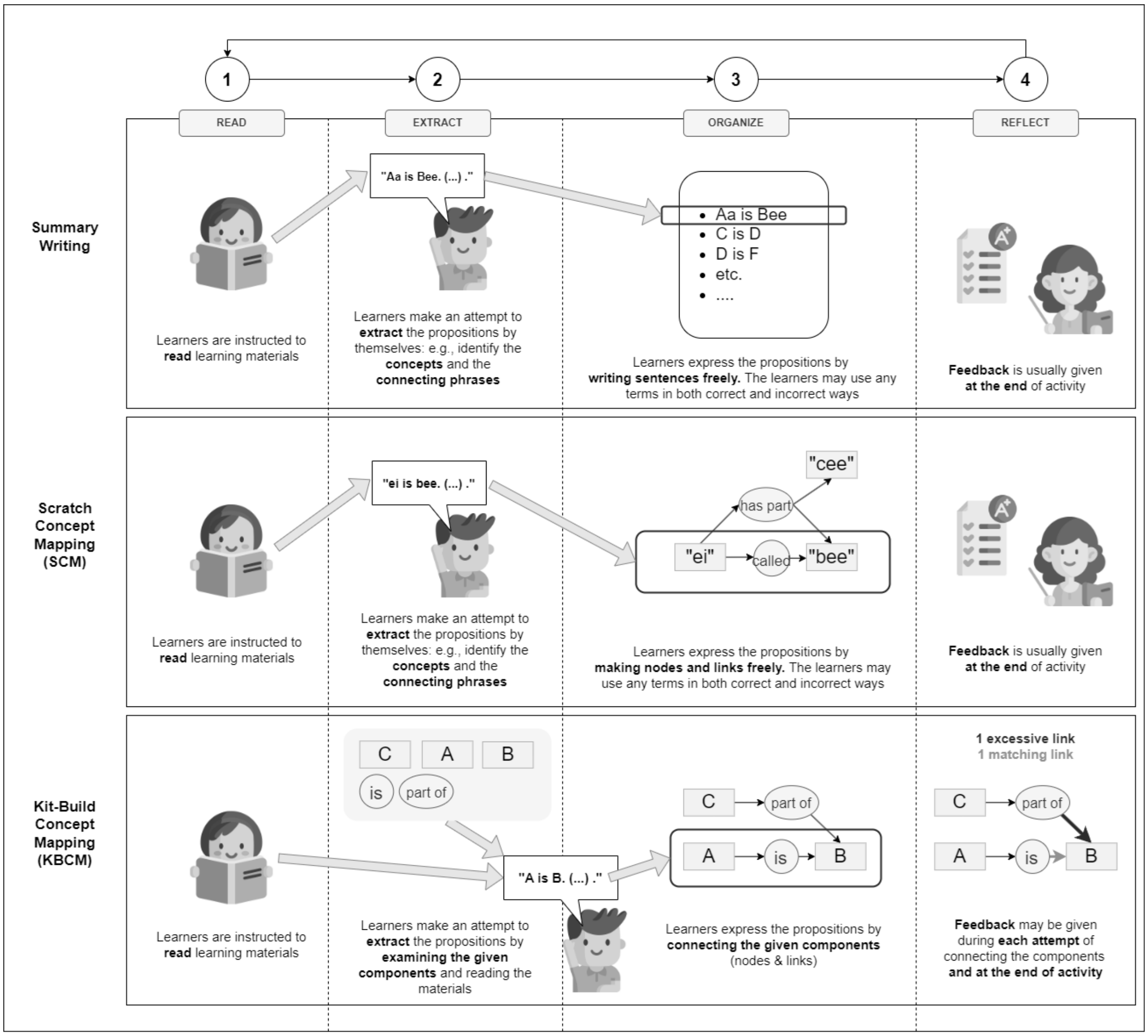
Information-organizing activities can be provided in various assignments, such as writing a summary and making a concept map. In summary writing, learners organize their understanding of the learning materials by paraphrasing them in their own words through the process of extracting the structure of the knowledge included in the materials, which may involve adding personal reflections on the materials (Pilegard & Fiorella, 2016). Despite some limitations, various studies reported the benefits of summary writing (Franzke et al., 2005; Lenhard et al., 2013; Sung et al., 2016).

Concept mapping is another alternative that can be provided for organizing information. Pioneered by Novak (1990) based on Ausubel's theory of meaningful learning (Ausubel, 2000), concept mapping is an activity that involves the use of a graphic organizer (the concept map) to enable learners to achieve meaningful learning by becoming aware of the structure of the knowledge domain, i.e., the relationships between concepts within a topic (Novak & Cañas, 2006).

There are various approaches to concept mapping, such as constructing a concept map from scratch (the traditional scratch concept mapping/SCM) and reconstructing a teacherconstructed concept map from components (kit-build concept mapping/KBCM) (Yamasaki et al., 2010). Figure 3 illustrates the differences between the mentioned approaches.

Figure 3

Summary Writing, Scratch-Concept Mapping, and Kit-Build Concept Mapping



Note. This figure is designed using images made by Freepik from Flaticon (https://flaticon.com).

Methods

Participants

This study involved 75 students from two linear algebra classes at a public university in Indonesia. One class was assigned as the experimental group (KBCM class; $n = 42$), while the other was assigned as the control group (summary writing class; $n = 33$). Note that this arrangement involved a more balanced sample size in comparison to the sample size used in the related prior study (Hasani et al., 2023). The participants' informed consent was collected prior to the study, and the data collected from the participants were anonymized. In addition, this study was approved by the teaching team of the involved classes due to the fact that the institutional review board was still in the process of being established. The demographics of the participants are shown in Table 1.

Table 1

Demographics of the Participants

	KBCM ($n = 42$)	Summary Writing ($n = 33$)
Gender		
Male	28	18
Female	14	15
Batch		
2022	42	33

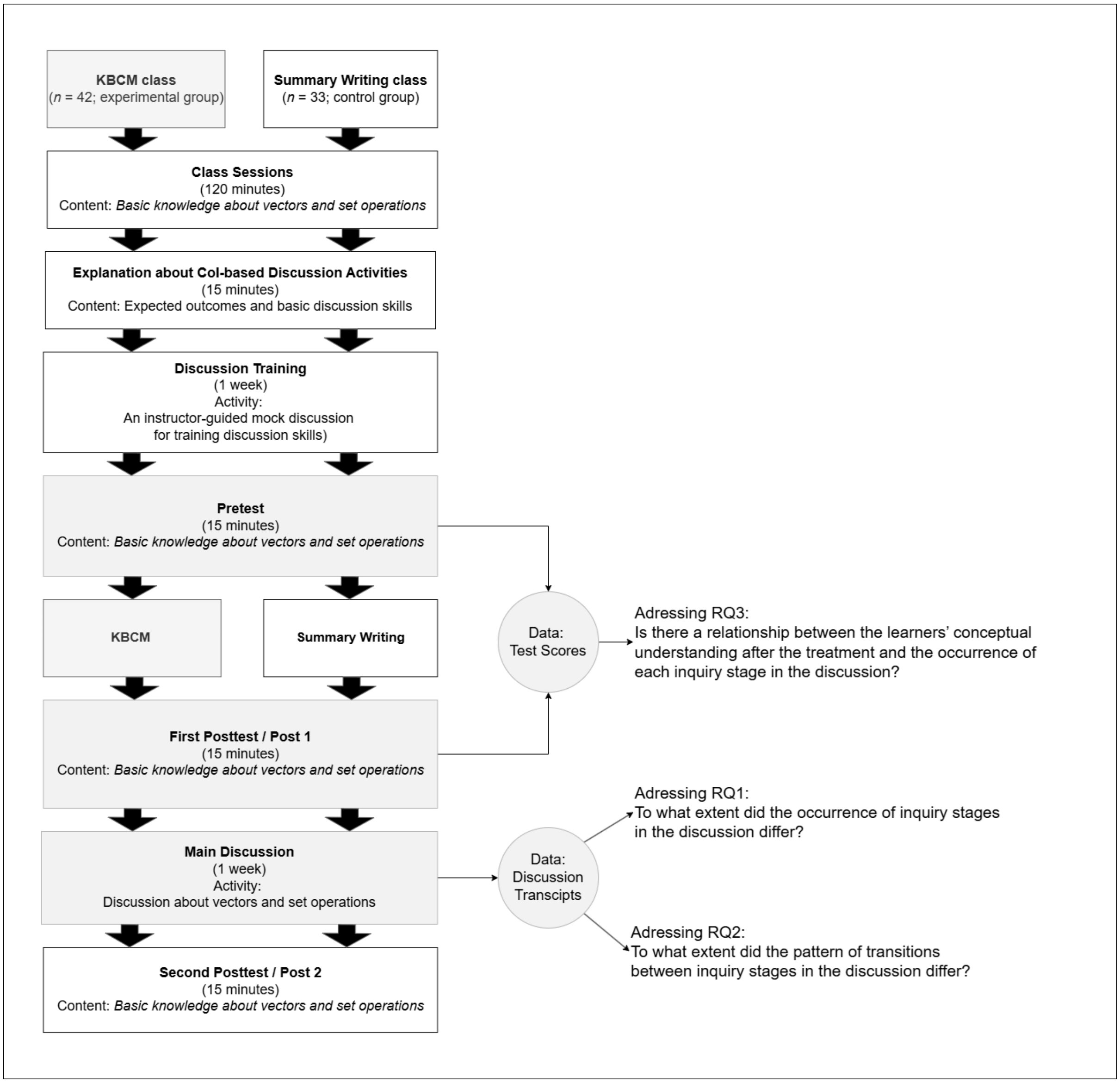
Learning Context and Procedures

The goal of the learning activity was similar to the one reported in the related prior study, which is being able to present a proof whether a set of given mathematical objects (e.g., functions, matrices, and polynomials) satisfies all vector space axioms (Hasani et al., 2023). To achieve the mentioned goals, learners were instructed to: (a) attend lecture sessions about the basics of algebraic vectors and binary set operations, which are the necessary conceptual knowledge for engaging in the discussion about vector axioms; (b) attend pre-discussion training (explanation on the basics of CoI-based discussion, best practices, and participation in a mock discussion); and (c) organize information related to the mentioned conceptual knowledge using different methods (KBCM for the experimental group and summary writing for the control group). Figure 4 illustrates the procedures conducted in this study.

After attending class sessions, learners in both experimental group (KBCM class) and control group (summary writing class) were divided into smaller discussion groups during the discussion training (1 week). The same discussion group arrangement was used for the main discussion activity (1 week). In this study, only the data from learners from 2022 batch were included for the analysis. There were three to seven learners in each discussion group (KBCM class: 9 discussion groups; summary writing class: 6 discussion groups). Figure 4 shows in detail the order and the duration of each activity.

Figure 4

Procedures and Data Collection



As displayed in Figure 4, learners' conceptual understanding was captured three times: before the information-organizing activities, before the discussion, and after the discussion. The conceptual knowledge test consisted of eight questions measuring the understanding of the conceptual knowledge about vector space axioms, which is related to the discussion topic.

Coding Process of the Discussion Transcript

The discussion transcript from the KBCM and the summary writing classes were retrieved from the Moodle forum and coded using a coding frame based on the works of Junus (2023) and Shea et al. (2010). Two coders independently coded the transcript, and then a reliability analysis was performed to check the discrepancies between the coding results and establish reliability as suggested by Campbell et al. (2013). To begin, the first coder coded the transcript. The meaning unit was one message, which might contain one or more descriptors of inquiry stages. The coding scheme and sample codes (excerpt) are shown in the Appendix. The second coder then coded a randomized sample of the transcript (30% of the messages). Both coding results were compared, and the Brennan-Prediger Kappa value (the reliability coefficient) was calculated using MAXQDA (https://www.maxqda.com/). The Kappa value of 0.98 was obtained, which is considered as almost perfect agreement according to Landis and Koch (1977). After the coders then discussed and reached a consensus regarding the discrepancies, the agreed coded transcripts were used for the analysis.

Data Analysis

In this study, RQ1 (To what extent did the occurrence of inquiry stages in the discussion differ?) and RQ2 (To what extent did the pattern of transitions between inquiry stages in the discussion differ?) were posed to investigate the difference in the discussion process of the KBCM and the summary writing treated classes based on: (a) the occurrence of inquiry stages and (b) the transition between inquiry stages. These are the factors that characterize the quality of online discussions. Additionally, RQ3 (Is there a relationship between the learners' conceptual understanding after the treatment and the occurrence of each inquiry stage in the discussion?) was posed to investigate whether the treatment was one of the factors that contributed to the discussion process.

For answering RQ1, we captured the number of messages containing each inquiry from both classes. In terms of the CoI framework, at least, increased quantities of the occurrence of each inquiry stage indicate better discussion. Among triggering event, exploration, integration, and resolution, the rate of messages containing each inquiry stage was calculated for both classes, and then, non-parametric statistical tests (Mann-Whitney and Wilcoxon signed rank tests) were performed. Holm's method was used to adjust the original p-values. The purpose of these statistical tests is to check the difference in the rate of messages containing inquiry stages between the classes. The effect sizes were interpreted according to a benchmark developed by Funder and Ozer (2019). The statistical tests were performed using R packages.

For answering RQ2, we captured the number of directed transitions between inquiry stages that were happening in the discussion groups of both classes. In addition to the quantities of the occurrence of each inquiry stage, in CoI-based discussion, the directed transitions among inquiry stages are important. Basically, CoI-based discussions are expected to proceed in the order corresponding to triggering event, exploration, integration, and resolution. In addition to that, according to the needs, learners can return to any one of the prior inquiry stages. Whether or not learners follow the such transition can be the criteria for conducting CoI-based discussions. To capture the pattern of directed transition, we use ordered network analysis (ONA) with discussion group as the unit of analysis. This is a technique for modeling the structure of connections in data.

Similar to epistemic network analysis (ENA), ONA assumes that: (1) it is possible to identify a set of meaningful features in the data (codes) systematically; (2) the data has local structure (conversations); and (3) an important feature of the data is the way that codes are connected to one another within conversations (Shaffer et al., 2016). However, in ONA, the order of appearance of each code in the data frame is accounted. Thus, ONA could uncover the directed connections between two or more codes within a coded data frame, i.e., the cumulative co-occurrence of two or more codes within one or several messages at a certain point with a certain sequence in a coded data frame (Shaffer et al., 2016). ONA generates a network representing the codes (nodes) and calculates the weight of the connections between the codes, which then allows a statistical test on the projected points in the ONA plane to be performed to determine whether two classes' discussion groups showed a different pattern of connections. In this study, the ONA was conducted through the ENA webtool (https://www.epistemicnetwork.org/) using the discussion transcripts retrieved from both the KBCM and the summary writing classes' discussion groups.

For addressing RQ3, we captured the pre-test and the first post-test scores. The former represents the baseline level of conceptual understanding before the treatment, while the latter represents the level of understanding after the treatment. To check if the improved conceptual understanding, as a result of the treatments, contributed to the discussion process, the correlations between the post-test scores and the rate of messages for each inquiry stage were calculated. Spearman's ρ correlation coefficients as well as the *p*-values were calculated to check whether significant correlations could be found between the pre-test, the first post-test, and the rate of messages containing each inquiry stage. A benchmark by Dancey and Reidy (2007) was used for interpreting the coefficients. The original *p*-values for each correlation were adjusted using Benjamini-Hochberg's method. Both the coefficients and the *p*-values were shown to avoid misunderstanding the strength and probability of the occurring relationship, as suggested by Akoglu (2018).

Results

Rate of Messages Containing Each Inquiry Stage

The KBCM and the summary writing classes showed a total of 105 messages and 83 messages, respectively**.** One message might contain more than one inquiry stage code. In addition, the teacher-created concept map was mentioned one time in the KBCM class, while in the summary writing class, the teacher-created summary was mentioned one time. Table 2 shows the descriptive statistics of the messages containing each inquiry stage from both classes.

Table 2

Descriptive Statistics of the Messages Containing Each Inquiry Stage

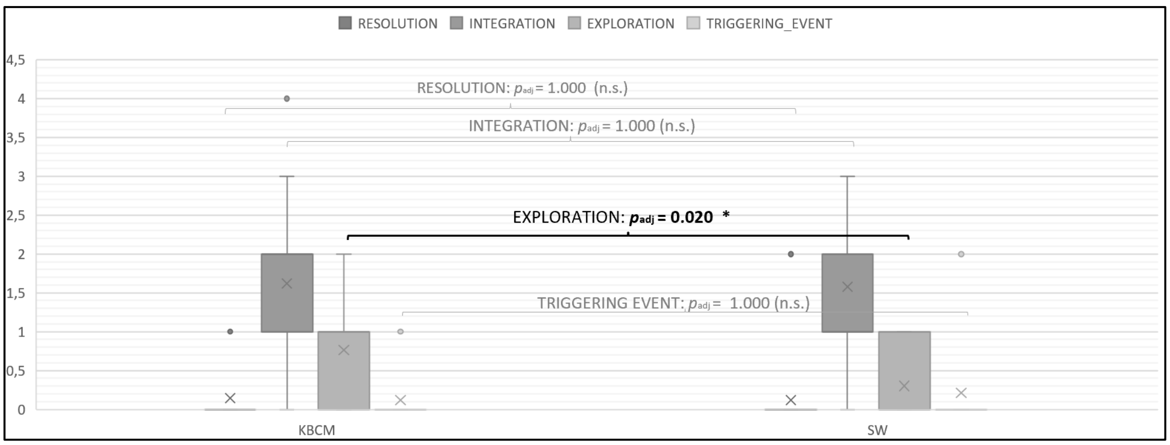
	Triggering Event		Exploration		Integration		Resolution	
	KBCM (*n*=42)	SW (*n*=33)	KBCM (*n*=42)	SW (*n*=33)	KBCM (*n*=42)	SW (*n*=33)	KBCM (*n*=42)	SW (*n*=33)
Total	5	7	32	10	68	52	6	4
Min	0	0	0	0	0	0	0	0
Max	1	2	2	1	4	3	1	2
Median	0	0	1	0	2	1	0	0
Mean	0.12	0.21	0.76	0.30	1.62	1.58	0.14	0.12

Note. KBCM: Kit-build concept mapping; SW: Summary writing.

Non-parametric tests (Mann-Whitney test) were performed on the data. After adjustment using Holm's method, the results show that the KBCM class showed a significantly higher rate of messages (i.e., number of messages per learner) containing exploration (original p-value: 0.005; adjusted p-value: 0.020; effect size r: 0.330 [large]). No significant differences were shown in the rate of messages containing other inquiry stages. Figure 5 shows the comparison of the rate of inquiry stages-containing messages between the KBCM and summary writing classes.

Figure 5

Number of Messages Containing Each Inquiry Stage Per Participant



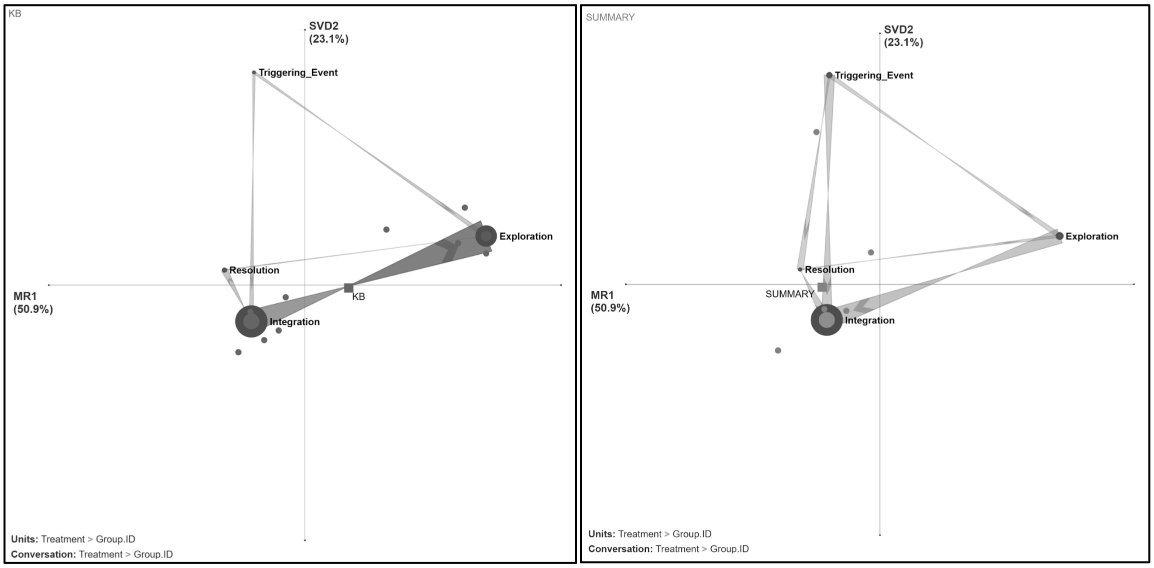
Note. KBCM: Kit-build concept mapping group; SW: Summary writing.

Transition Between Inquiry Stages

The ONA plot illustrates the directed transitions between inquiry stages that were conducted by the learners in discussion groups in both KBCM class (9 discussion groups) and summary writing class (6 discussion groups). The nodes represent the inquiry stages, whereas the directed links represent the existence of certain directed transitions between the inquiry stages. The thickness of the links represents the weight of the transitions, i.e., the number of the co-occurrence of two inquiry stages within two adjacent messages across the conversations in a discussion group. Figure 6 shows the ONA plot illustrating the transitions between the inquiry stages that were made by learners within the conversation of the discussion groups in the KBCM (left) and summary writing (right) classes with the projected points showing each discussion group. Mean rotation was applied to place the means of the projected points of the two classes with different treatments (KBCM & summary writing) as close as possible to the x-axis, which maximizes the distances between them, as described by Tan et al. (2024). The x-axis represents the rotated SVD1, while the y-axis represents the SVD2, which were obtained from the dimensional reductions of the vectors that represent the pattern of transition between inquiry stages (co-occurrences of inquiry stage codes).

Figure 6

The Connections Between Inquiry Stages in the KBCM and Summary Writing Classes



Note. Left: KBCM discussion groups' connections; Right: Summary writing discussion groups' connections.

We checked whether the discussion groups of the two classes have different patterns of directed transitions between the inquiry stages. The square points represent the mean values of the x and y axes for each class, and they are plotted in different locations. In ONA, it is possible to perform statistical tests using these representative values on the two-dimensional plane between the two classes. This approach has been used in prior studies in CoI-based discussion, e.g., Rolim et al. (2019), that used epistemic network analysis (ENA)–Note that ENA is in principle similar to the ONA except in terms of the order of codes' appearances. The non parametric permuted Brunnel-Munzel tests were conducted for each of the x and y axes between the classes (Neubert & Brunner, 2007). The results are shown in Table 3.

Table 3

Non-Parametric Test of Significance for The Projected Points in The ONA Plane

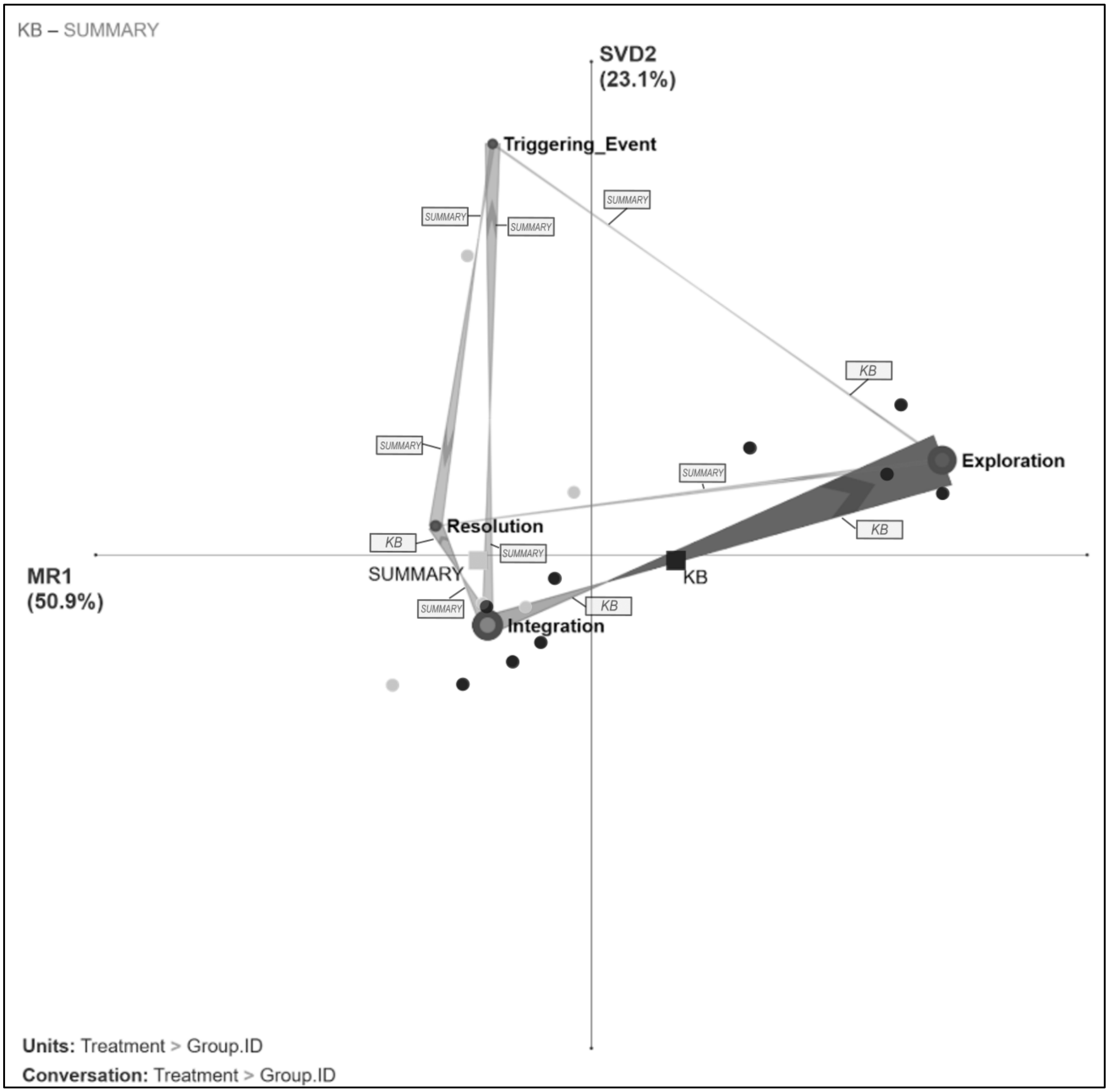
	Median		p	Effect size (stochastic superiority)
	KBCM (n_{group} = 9)	SW (n_{group} = 6)		
x-axis: MR1	-0.081	-0.253	**0.038 ***	0.815 (large)
y-axis: SVD2	-0.051	-0.111	0.580 (n.s.)	0.593 (small)

Note. KBCM: Kit-build concept mapping group; SW: Summary writing.

The non-parametric tests of the projected points shown in Table 3 checked if the discussion groups in the two classes exhibited a different pattern of directed transitions between inquiry stages based on the whole network that was projected on the ONA plane. A significant difference in either x or y axes indicates a significantly different pattern shown by the discussion groups in the two classes. In addition, the simple comparison shown in Figure 7 can show in what manner the mentioned pattern of directed transitions differed between the classes (e.g., what directed transitions appeared or not appeared in the discussion groups of one class, etc.). Based on the results shown in Table 3 and Figure 7, the discussion groups from the KBCM and summary writing classes exhibited a different pattern of transitions between inquiry stages, in a way that (a) the discussion groups in the KBCM class tended to show more integration→exploration, which is acceptable (e.g., exploring materials after integrating some ideas to support arguments), as well as more integration→resolution (one of the expected transitions according to the practical inquiry model) and (b) the learners in the summary writing group tended to show more integration→triggering event, which may be a reasonable transition (e.g., asking questions after integrating some ideas) and more triggering event→resolution, which may indicate some jumps skipping the stages of exploration and integration.

Figure 7

Comparison Plot of the KBCM and Summary Writing Classes



Note. The labels on connections in the figure indicate which group—KBCM or summary writing—has a higher weight (representing the numerically larger value, not based on statistical test results). The projected points represent the discussion groups in both classes (KBCM: black; summary writing: gray).

Conceptual Knowledge Understanding

The following tests of conceptual knowledge related to the discussion topic were administered: (a) the pre-test (after the lecture session before the information-organizing activities), (b) the first post-test (after the information-organizing activities before the discussion), and (c) the second post-test (after the discussion). The descriptive statistics of the scores for the mentioned tests are shown in Table 4.

Table 4

Descriptive Statistics of The Conceptual Knowledge Test Scores

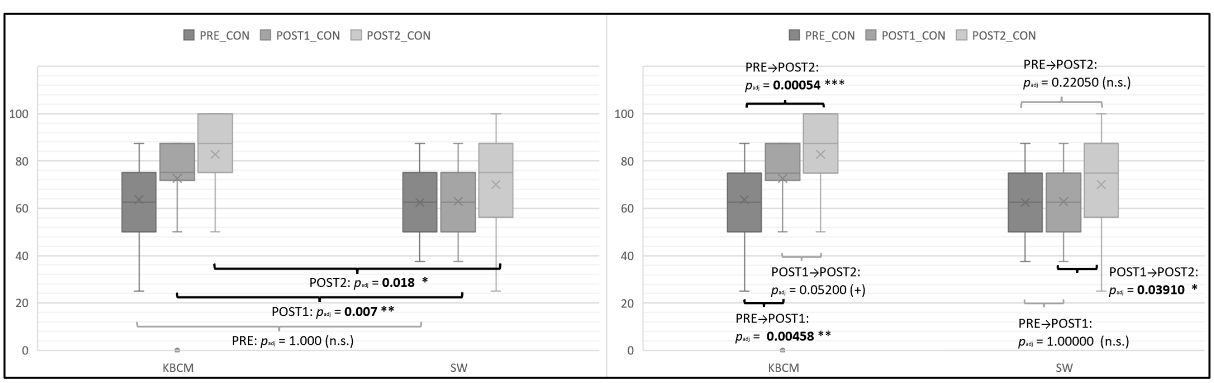
	Pre-test		First Post-test		Second Post-test	
	KBCM (n=42)	SW (n=33)	KBCM (n=42)	SW (n=33)	KBCM (n=42)	SW (n=33)
Min	25.00	37.50	0.00	37.50	50.00	25.00
Max	87.50	87.50	87.50	87.50	100.00	100.00
Median	62.50	62.50	75.00	62.50	87.50	75.00
Mean	63.69	62.50	72.62	62.88	82.74	70.08

Note. KBCM: Kit-build concept mapping; SW: Summary writing.

The test scores of both the KBCM and summary writing classes were compared using non-parametric tests (Mann-Whitney & Wilcoxon tests). The p-values were calculated and adjusted using Holm's method. The results of the tests showed that both classes started from the same level of conceptual knowledge related to the discussion topic (original p-value: 0.621; adjusted p-value: 1.000). After the treatment (before the discussion), the KBCM class showed a significantly higher score for conceptual knowledge compared to the summary writing group (original p-value: 0.001; adjusted p-value: 0.007; effect size r: 0.420 [very large]). In addition, only the KBCM class experienced a significant increase in the test scores before the discussion (original p-value: 0.000573; adjusted p-value: 0.004584; effect size r: 0.514 [very large]). Figure 8 shows the comparisons for the pre-test, first post-test, and the second post-test scores of both the KBCM and summary writing classes.

Figure 8

The Test Scores Measuring Conceptual Understanding Related to Discussion Topic



Note. KBCM: Kit-build concept mapping; SW: Summary writing.
The diagram on the left shows inter-class comparisons, while the diagram on the right shows the comparisons of the change in the test scores.

After the discussion, the KBCM class scored significantly higher for the second post-test than the summary writing class (original p-value: 0.003; adjusted p-value: 0.018; effect size r:

0.340 [large]). However, only a marginally significant increase in the test scores (the first and the second post-test) was observed in the KBCM class.

Correlation Between the Conceptual Knowledge Level Before the Discussion and the Rate of Inquiry Stage-Containing Messages

Correlation analysis was conducted to investigate whether there are relationships between learners' understanding of conceptual knowledge related to the discussion topic and the occurrence of each inquiry stage they performed during the discussion. Table 5 shows the correlation table showing the Spearman ρ values for each variable.

Table 5

Correlation Analysis Between The Inquiry Stages, Pre-Test Score, and The First Post-Test Score

	Triggering Event	Exploration	Integration	Resolution	Pre-test	Post 1
Triggering Event		0.22 (p = 0.0636)	0.13 (p = 0.2770)	0.22 (p = 0.0605)	0.06 (p = 0.5997)	-0.02 (p = 0.8815)
Exploration	p_{adj} = 0.7655		-0.12 (p = 0.3107)	0.02 (p = 0.8532)	0.12 (p = 0.3210)	0.42 (p = **0.0002**)
Integration	p_{adj} = 0.5675	p_{adj} = 0.6019		0.15 (p = 0.1910)	0.09 (p = 0.4414)	0.05 (p = 0.6634)
Resolution	p_{adj} = 0.4537	p_{adj} = 0.8815	p_{adj} = 0.5675		0.15 (p = 0.1878)	-0.06 (p = 0.6320)
Pre-test	p_{adj} = 0.7655	p_{adj} = 0.6019	p_{adj} = 0.6857	p_{adj} = 0.5675		0.17 (p = 0.1430)
Post 1	p_{adj} = 0.8815	p_{adj} = **0.0030**	p_{adj} = 0.7655	p_{adj} = 0.7655	p_{adj} = 0.5675	

Note. The Spearman ρ values are shown outside the brackets in the upper diagonal.
The original p values are shown inside the brackets in the upper diagonal.
The BH method adjusted p values are shown in the lower diagonal.
Post 1: The first post-test.

After adjustment using Benjamini-Hochberg's method, there was a significant and moderate correlation between the first post-test score and the rate of exploration messages (Spearman ρ: 0.42). No significant correlation was observed between the test scores and the other inquiry stages (adjusted p-value ≥ 0.05).

Discussion

Answering RQ1: To what extent did the occurrence of inquiry stages in the discussion differ?

The results regarding the rate of messages containing each inquiry stage indicate that learners in the KBCM class tended to perform more *exploration* in discussion (see Figure 5). Many studies reported that exploration is the most performed inquiry stage (Liu & Yang, 2012; R. L. Moore & Miller, 2022; Olesova et al., 2022). Despite being less intellectually demanding to perform compared to the higher-level stages of integration and resolution, exploration is an important part of the inquiry process in which learners try to gather and share ideas from relevant sources for proposing initial solutions or completing tasks (Garrison et al., 2001; R. L. Moore & Miller, 2022). As a result, a higher number of explorations may provide diverse ideas for the learners to engage in debates on the solution during the integration stage.

Related prior studies with less balanced sample sizes found that KBCM has the potential to be better at fostering triggering event, exploration, and integration messages as well as fostering more critical thinking in a discussion compared to the traditional summary writing (Hasani et al., 2023, 2024; Hasani, Junus, Sadita, Hirashima, et al., 2025). A concept map generally provides common vocabularies and terms used within a knowledge domain (Colosimo & Fitzgibbons, 2012; Novak & Cañas, 2006). Therefore, it has been suggested that if a concept map represents the knowledge related to a topic of a discussion activity, using it potentially increases learners' awareness of the common terms and the interconnected concepts related to the topic (Hasani et al., 2023). This is in line with past studies on concept mapping in general, which suggested the potential of concept mapping as a visualized knowledge representation to enable learners to recognize relationships between concepts and encourage discussions (Baroody & Bartels, 2000; Davies, 2011).

The learners in the KBCM class might conduct more exploration than the summary writing group because they are able to recognize the correct terms to search for relevant resources and form initial answers to the problem posed in the discussion. Williams (1998) suggested that a concept map also represents knowledge fluency (e.g., the use of correct terms representing an idea in a knowledge domain); thus, being able to make one reflects its maker's fluency in the knowledge domain. In contrast, the learners in the summary writing class might have less awareness about the correct terms used in the knowledge domain due to the freedom to use any terms they like when writing the summary despite being provided with a list of keywords as a guide. In a worse case, learners might have performed verbatim copy-paste of the sentences when writing the summaries, which may constitute a non-reflective process as recalling word by word does not mean comprehension (Chuenchaichon, 2022; Spirgel & Delaney, 2016; Wang & Yu, 2024). Thus, different individuals might make a different summary with various qualities. The difficulty in making well-organized and accurate summaries (e.g., using correct terms, no copy-paste sentences), as suggested by Pilegard and Fiorella (2016), might have led to less awareness of the correct terms and concepts in the summary writing class and contributed to the lower exploration in the summary writing class.

However, in regards to the differences in the results of this study and the prior studies on KBCM (e.g., Hasani, Junus, Sadita, Hirashima, et al., 2025), there is an indication that other factors might have played a significant role in affecting the potential of KBCM for fostering *other* inquiry stages. One of the possible influential factors is whether the learners actively mentioned and referred to the teacher-created map throughout the discussion. The teacher-created concept map and summary were mentioned only once in the respective classes. As a result, there was a possibility of inert knowledge in both groups, which might have led to the low amount of triggering event and resolution-containing messages in both groups and the similar amount of integration between the two classes. Inert knowledge is acquired knowledge that was not used when necessary during specific problem-solving episodes (Renkl et al., 1996).

Explicit mentioning of the teacher-created map or summary may trigger (activate) reflection on the information-organizing activity; lacking it may hinder the full potential of KBCM and summary writing. Past studies emphasized the importance of reflection and providing direct instruction for effective progression through inquiry stages (Garrison, 2019; Garrison et al., 2001; Pawan et al., 2003). Therefore, as a practical implication, direct instruction to reflect on the KBCM attempt is recommended to encourage learners to recall and reflect on the knowledge they organized during the KBCM attempt, thus encouraging further progression through inquiry stages.

Answering RQ2: To what extent did the pattern of transitions between inquiry stages in the discussion differ?

The results of the ONA show that the KBCM and the summary writing discussion groups experienced a *significantly different pattern of directed transitions* between inquiry stages (p = 0.038 on the x-axis of the projected ONA plane) in which: (a) the KBCM discussion groups showed a tendency to *transition from integration to exploration,* which is an acceptable transition that may be performed in discussion, as well as to *transition from integration to resolution*, which is a necessary transition (see Figure 7); and (b) the summary writing discussion groups showed a tendency to transition from *integration to triggering event*, which is also acceptable considering the possibility of questioning after integration, and *from triggering event to resolution*, which is a jump skipping exploration and integration. The transition between exploration and integration, as well as between integration and resolution, are important transitions that learners need to perform in a meaningful inquiry. Spending sufficient time to perform preceding inquiry stages before progressing to the next is the characteristic of a scientific inquiry, which served as the basis of the CoI framework (Garrison, 2016). Thus, considering the tendency of jumping the stages among summary writing discussion groups, the KBCM discussion groups showed better patterns of inquiry compared to the summary writing group.

Doing exploration after integration may indicate an attempt to reevaluate understanding expressed during the idea integration by providing relevant learning materials that shows exploring ideas, as described in the descriptors of exploration (Garrison et al., 2001). Concept mapping, in general, has to help learners realize the relationship between important concepts (Davies, 2011). Therefore, KBCM, as a type of concept mapping activity, might have helped learners make connections between ideas and trigger them to share relevant information and brainstorm expressed ideas after seeing a series of organized information in the discussion thread.

A past study on inquiry stages emphasized the importance of enabling the learners to progress from exploration to integration and, finally, resolution (Garrison et al., 2001). Learners have been reported to experience difficulty integrating and building on others' ideas (Pawan et al., 2003). A related past study with unbalanced sample sizes showed that KBCM has the potential to enable learners to experience the following transitions: Triggering event-exploration-integration (Hasani, Junus, Sadita, Ayano, et al., 2025). In regards to the findings, this study provides further evidence that, compared to summary writing, KBCM is mostly effective for encouraging integration→exploration and integration→resolution, which is one of the important transitions that are usually difficult to surpass, as suggested in some studies that showed relatively low amounts of messages containing higher-level inquiry stages (Bissessar et al., 2020; Garrison et al., 2001; Lee, 2014; Vaughan & Garrison, 2005).

Answering RQ3: Is there a relationship between the learners' conceptual understanding after the treatment and the occurrence of each inquiry stage in the discussion?

The correlation analysis suggested a moderate yet *significant and positive* correlation between the learners' *conceptual understanding* after the treatment and the *rate of exploration* messages in the discussion (Spearman's $\rho = 0.42$; $p_{adj} = 0.003$), as shown in Table 5. This result indicated that the learners' conceptual knowledge, as one of many factors, contributed to their discussion behavior in exhibiting exploration messages.

As for the possible explanation of this finding, having an improved conceptual understanding of the discussion topic-related knowledge, i.e., knowledge of the concepts and their relationships (Crooks & Alibali, 2014), might have helped learners to search for relevant resources more effectively (e.g., from books, the internet, etc.). This aligns with a prior study that suggested that having internalized knowledge affects exploratory behavior during a discussion (Hou et al., 2009). In the KBCM class, a better awareness of relevant terms as well as how the terms are interrelated (i.e., internalizing knowledge) may lead to an ease of searching the relevant resources, which, in turn, encourages the learners to share their first thought on the solution based on the resources that they have read or shared. This finding supports prior studies that asserted the potential of concept mapping to develop conceptual understanding (Montpetit-Tourangeau et al., 2017; Varoglu et al., 2023).

Conclusion

Making learners actively perform the inquiry process in an online discussion is difficult, particularly among novice students. KBCM has been suggested as an alternative to improve discussion preparatory activities to realize a productive inquiry. However, there is a lack of evidence regarding KBCM's effect on discussion quality that involves comparison with the typical summary writing under a balanced sample size. Thus, its effectiveness needs to be confirmed. This study proposes and provides further evidence of the KBCM's effectiveness as an alternative information-organizing activity within pre-discussion preparation for improving online discussion quality. The KBCM and summary writing classes showed a significantly different pattern of directed transitions between inquiry stages. The results indicate that KBCM is more effective for: (a) fostering exploration; and (b) encouraging integration→exploration and integration→resolution transitions compared to the traditional summary writing. Moreover, there was also a significantly higher rate of exploration in the KBCM class and a significantly positive correlation between the rate of exploration and the first post-test scores. Learners' conceptual knowledge related to the discussion topic was found to be one of the factors associated with the rate of exploration messages in the discussion. Better improvement in the conceptual knowledge in the KBCM class might have influenced learners' exploratory behavior. In addition, whether learners mentioned and reflected on their KBCM attempts was suggested to be one of the other influential factors. Thus, direct instruction to actively make use of the concept map and to reflect on the KBCM attempts is recommended to maximize the effect of KBCM for improving discussion. Despite involving comparisons with balanced sample sizes, this quasi-experimental study is limited to conducting the experiment in: (a) real classroom settings where many other factors might have played an influential role; and (b) a specific mathematics subject. Therefore, the findings could not yet be generalized. Future studies may be conducted in other learning contexts.

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Declarations

Due to the fact that the institutional board had not yet been formed when this study was being conducted, this study has received ethical clearance and has been approved by the teaching team of the involved classes.

Conflict of Interest

The authors declare no conflict of interest in this study.

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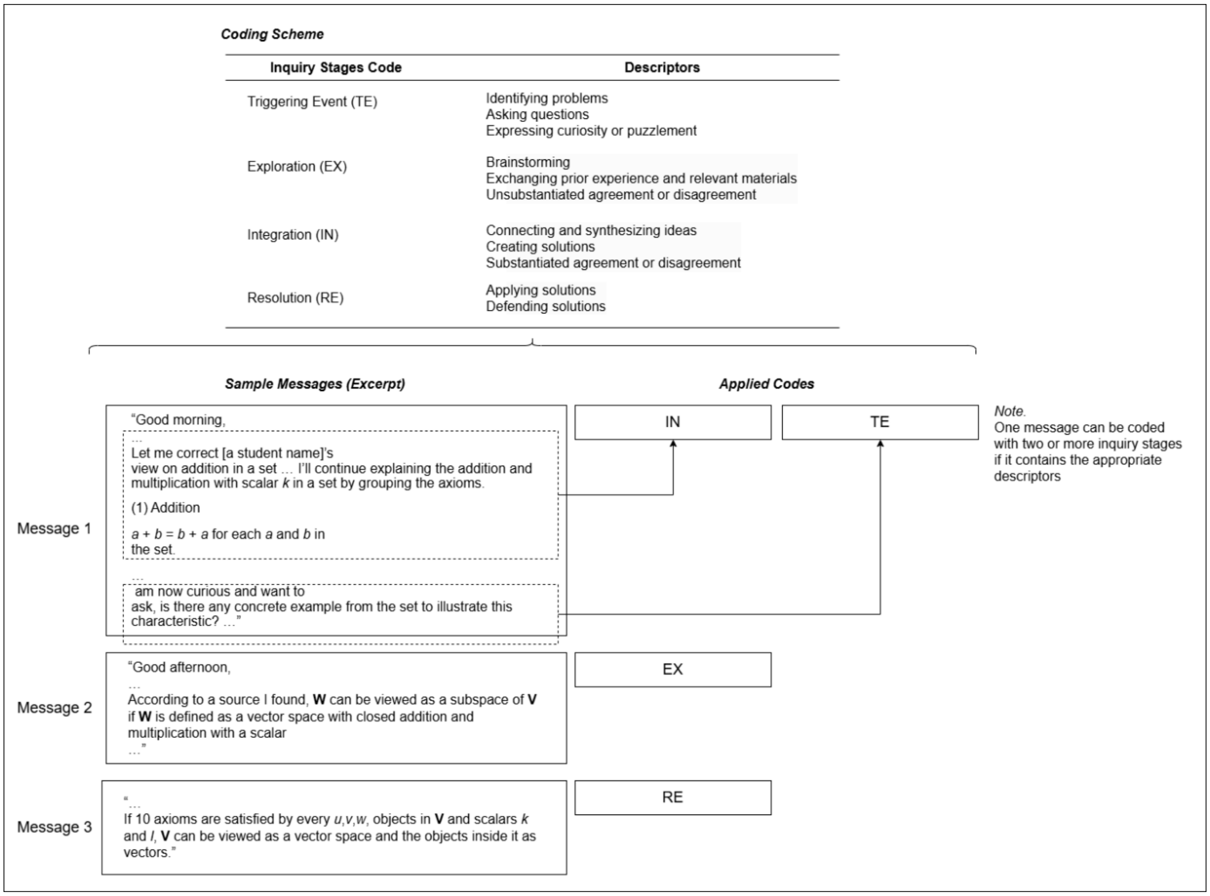
Appendix

Coding Scheme and Examples of Coded Messages (Excerpt)



Note. The descriptors were based on Shea et al. (2010) and Junus (2023)