Rodrigo, M. M. T. et al. (Eds.) (2021). Proceedings of the 29th International Conference on Computers in Education. Asia-Pacific Society for Computers in Education

Laboratory Study on ICAP Interventions for Interactive Activity: Investigation Based on Learning Performance

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Abstract: Research on collaborative learning indicates that knowledge deepens through conversations. However, studies on providing prompts for support of collaborative learning have investigated support focusing on only interactive activities in the collaborative learning process much. The purpose of this study is to investigate the effect of providing interventions that respond to keywords based on the ICAP theory to facilitate collaborative learning process included subordinate processes based on the Interactive-Constructive-Active-Passive (ICAP) theory that learning science has focused on collaborative learning process. We make prompts responding to keywords to investigate whether learning performance is facilitated through them. Additionally, we set the control condition, random condition, and keyword condition. In keyword condition, systems detected keywords on ICAP, classified into interactive, constructive, active, and passive. As a result, the learning performance of learners in the keyword condition was higher than in the control condition. Consequently, prompts focusing on ICAP based on keywords are considered to have been effective in facilitating learning performance. This study also deals with issues and research contents that should be analyzed in the future.

Keywords: Collaborative learning, computer-supported collaborative learning (CSCL), ICAP framework

1. Introduction

In various fields such as learning science and cognitive science, both individual learning and collaborative learning have been studied. The effectiveness of collaborative learning is supported by the zone of proximal development theory, and it is understood that things that cannot be achieved as individuals can be achieved by collaborating with others (Vygotsky, 1980). Kupczynski, Mundy, Goswami, and Meling (2012) found that collaborative methods facilitate learning over individual methods in distance learning situations. Distance learning situation refers that learners cannot see each other, and learners learns in remote. However, it is difficult for teachers to provide appropriate guidance for each group, and the development of a support system independent of humans is needed.
Computer assisted instruction (CAI) was first investigated in research dealing with computer assistance. In recent years, there have been advancements in intelligent tutoring systems to provide adaptive feedback based on cognitive activity, with a focus on individual learning (Anderson, Corbett, Koedinger, & Pelletier, 1995). In contrast, computer-supported collaborative learning (CSCL) provides support using prompts that ask questions, and instructions and scripts that pre-specify learning activities to foster important processes in collaborative learning based on its theory. (Weinberger, Ertl, Fischer, & Mandl, 2005).

Many collaborative learning theories have been investigated, and it is necessary to study a system that supports collaborative learning based on them. In particular, in learning science research, there are many studies on the learning process (Meier, Spada, & Rummel, 2007). One of the studies examines the Interactive-Constructive-Active-Passive (ICAP) theory, which reveals that the learning process changes in stages, such as passive, active, constructive, and interactive (Chi & Wylie, 2014). It is suggested that it is important in learning science that learning process that learners contribute each

other affect learning performance. Therefore, Our research group has investigated creating prompts based on cooperative and argumentative processes and presenting them randomly so far (Shimojo & Hayashi, in press). Consequently, it was found that learning is facilitated by randomly presenting prompts. However, the conversation process based on the ICAP theory was not observed sufficiently, and the change from passive to interactive was not fully clarified (Shimojo & Hayashi, 2020).

In this study, we focused on collaborative learning in distance situations. To facilitate a conversation process based on the ICAP theory, we detected keywords in conversation and investigated the effect of facilitating learning performance by presenting prompts accordingly. First, in this section, I will describe the ICAP theory that this study focuses on, introduce research to facilitate collaborative learning processes, and describe the purpose and hypothesis of this research based on these points. Second, I mainly explain how to conduct experiment and provide prompts. Third, I show the result of hypothesis testing and then discuss the result. Final, I summarize this paper.

1.1 ICAP Theory and Support for Collaborative Learning Based on ICAP Theory

In learning science, constructive interactions that share ideas and examine them are important (Miyake, 1986). Previous studies have focused on various collaborative learning processes, but this research focuses on the ICAP theory. The reason is that it is possible to grasp the depth of the process and to make a clear policy to support the passive voice to interact.

The ICAP theory (Chi & Wylie, 2014) classifies collaborative learning processes into interactive, constructive, active, and passive, and states that interactive is the deepest process where learning is most facilitated. Passive is where the person simply receives information on learning materials, active is where there is paraphrasing or repetition of learning materials, constructive process entails a deep understanding of learning materials, and interactive is an activity that further deepens understanding through interaction with others. The interactive process builds one's own opinion based on the opinion of the partner. These processes have a hierarchical structure. Therefore, in supporting collaborative learning, it is important to encourage learners to active, constructive, and interactive for facilitating interactive. The hypothesis that learning performance is facilitated as it becomes interactive, as mentioned earlier, is supported by the knowledge change process. In the passive process, learners simply store new information (store); in active, new information activates related prior knowledge and stores it in an integrated manner (integrate); in constructive, new information is integrated and inferred from active knowledge (infer); and finally, in the interactive process, each learner infers new knowledge from integrated/activated knowledge and from others (co-infer). That is, as the learner's activities become interactive, the knowledge deepens. Wiggins, Eddy, Grunspan, and Crowe (2017) investigate instructor support but find it difficult to engage learners interactively because it is difficult to facilitate the interactive process due to lack of time and human resources in the scene of large-scale collaborative learning with human support. Therefore, to facilitate interactive learning process in the order mentioned above, support for prompts based on context and timing using computer systems is required.

Accordingly, insufficient time and human resources are available in the case of purely human support, and thus, collaborative learning support using a computer is required. In the next section, we describe what kind of support method is useful for encouraging learners' interactive activities.

1.2 Facilitation of Collaborative Learning Process by Using Computer

Various studies in CSCL have been investigated to facilitate collaborative learning processes using computers. For example, Weinberger, Ertl, Fischer, & Mandl (2005) conducted a combined script and prompts, facilitating the processes at each stage, and demonstrating their usefulness not only text-based but also oral. Therefore, prompts are useful for facilitating a particular collaborative learning process. However, pre-ordered support such as conventional scripts has over-script problems, such as reduced motivation (Dillenbourg, 2002). Therefore, it is necessary to consider collaborative learning support based on the context and timing of collaborative learning.

Among such collaborative learning support, studies have examined the support methods for specific learning activities using agents. For example, Hayashi (2020) studied support using prompts and sensing technology. It has been clarified that learning performance is facilitated by detecting simple

information such as keywords from conversations to facilitate collaborative learning processes and using prompts according to the context and timing to some extent. The effectiveness of contextual and timing-based prompts is to provide relevant support, and it has been found that providing such support fosters learning activity and facilitates learning performance (Walker, Rummel, & Koedinger, 2014). As a method of verifying the effect of support according to the context and timing, a method of comparing the control condition without support, random prompts condition and adaptive condition is used. However, as we have seen, it is insufficient to consider presenting prompts according to the context and timing from the viewpoint of the collaborative learning process. Therefore, to facilitate interactive, prompts that can foster a specific conversation activity is effective, and when investigating the prompt effect according to the context and timing, it is possible to compare it with random presentation.

Therefore, in this study, we examine whether it is more effective to provide related interventions considering context and timing than to randomly present interventions when facilitating interactive activities. As a method, prompts that respond to ICAP-based keywords are presented, and when a keyword related to the passive process is detected, prompts related to the active are presented to prompt the related process. After that, the learner's conversation activity is facilitated for interactive in the same way. Since ICAP is an activity classified mainly based on utterances, it can be classified by utterances, and the keywords included in the utterances related to each activity are clear according to the task. Therefore, it is possible to detect keywords related to each activity to a certain extent, and it is possible to present prompts according to the context and timing.

1.3 Purpose and Hypothesis

The purpose of this study is to improve learning performance (pre-post test) by providing interventions that respond to keywords based on the ICAP theory to facilitate interactive process of a pair of learners during conversation. It is necessary to clarify whether it is facilitated. Therefore, to investigate the effect of presenting interventions that facilitate the interactive activities in response to keywords related to ICAP in oral dialog are provided, the following hypothesis is given and verified in the result section.

H1: Learners who are provided with ICAP interventions have better learning performance than learners who are not presented with ICAP interventions.

H2: Learners who are provided with ICAP interventions that respond to keywords related to ICAP are better at learning performance than learners who are provided with ICAP interventions randomly.

2. Method

2.1 Participants and Design

Participants in the experiment were 62 university students majoring in psychology. The average age was 19.21 years (*SD* = 1.08), and 18 were male and 44 were female. One pair of participants was excluded because of missing data.

In this study, we adopted a one-factor between-subject plan to examine two hypotheses. The inter-subject factor is a factor in the presentation of the prompt method, and three conditions were set, which were: control conditions, random conditions, and keyword conditions. Under the control conditions, only two people worked on the task without ICAP prompts on the screen. Under the random condition, prompts to facilitate ICAP was randomly presented on the screen while the two people were working on the task. In the keyword condition, as in the random condition, prompts to facilitate ICAP while working on the task by two people was presented on the screen. However, the presentation method detected keywords related to ICAP rather than random, and the prompt was presented based on the state of the ICAP. The specific system configuration is described in the section on the system structure below.

Participants in the experiment were randomly assigned to each of the three conditions and paired. Next, a test was used to confirm prior knowledge about causal attribution of whether there was any difference between the conditions. There was no difference between the conditions in the prior

knowledge of cause attribution, which is a concept to be learned (F (2,57) = 2.11, p = 0.13, *partial* η^2 = 0.07). Also, they did not know about cause attribution so much.

2.2 Materials

The materials used in this study were learning texts on attribution theory, which is a concept to be learned, episodes for experimental tasks, and concept maps, which are tools used in experimental tasks.

2.2.1 Learning Text and Experimental Task

The learning texts were about attribution theory, a psychological theory about the causal attribution of success and failure. Specifically, the text explained the important concepts in the attribution of causes of success and failure: external/internal, stable/unstable, controllable/uncontrollable.

In this task, we infer the mental model of Peter, one of the characters, using the cause attribution of success and failure learned in this learning text. Peter is a student who feels anxious in the new semester, and learners was asked to read his episode and infer the mind of him by using causal attribution of success and failure. When making the inference, he created it using a concept map. This task was created based on Weinberger and Fischer (2006).

2.2.2 Concept Map

In this study, CmapTools (https://cmap.ihmc.us/) was used. Creating a concept map is effective for learning and is used for discussions in collaborative learning. During the task, it was necessary to share the concept map created by the individual with the collaborators and to create one concept map by two people. Figure 1 illustrates a screen capture of the collaboration.

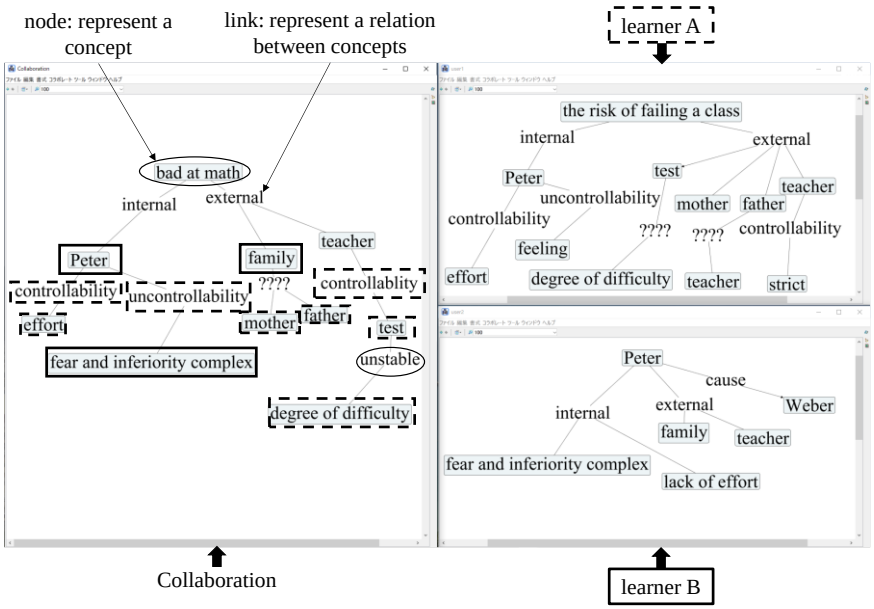

Figure 1. Screen Shot of Cooperation in this Task. Dotted line is for learner A and the solid line is for learner B. The ellipse is not included in either, and the rest are common.

2.3 Procedure

This experiment consists of three tests (check test, pre-test, post-test), a concept map explanation, a learning textbook, and the experimental task in individual and collaborative situations. Next, the specific procedure is explained.

First, a check test was performed to confirm whether the prior knowledge level was equivalent between the conditions. Next, the experimenter explained the concept map used in this task—that it consists of the relationship between concepts. After that, learners read and studied the prescribed

textbook and answered the pretest. In this task, we asked them to infer Peter's mental model individually using a concept map and then collaborate to create a concept map. Finally, learners answered the post-test. The only difference between the conditions was the collaboration phase of this task.

2.4 Structure of Prompt System

In this study, we used different systems for random conditions and keyword conditions. The installed prompts are of the same type in random and keyword conditions, created using C#, and TCP/IP communication was used for communication. First, the random condition presented prompts at random. In other words, the order of prompts was random.

In the keyword condition, a keyword list was first created to detect keywords related to ICAP. Figure 2 shows the example of keyword detection. The utterance of learner A was classified into active because "Peter" and "teacher" were in the list of "text" and "math" and "effort" were in the list of "cause". Since the active process entails an utterance that repeats the information of the learning material, we used keywords such as effort, cause attribution and internal/external in the learning material. Also, we used keywords combined 3 dimensions (e.g., stable and unstable) and cause because constructive is a process that learners deepen text and infer cause based on 3 dimensions. Furthermore, we used keywords of collaboration in addition to constructive. The presentation method is to first recognize the keyword using voice recognition, detect the current process of ICAP, and if it is passive, present prompts to facilitate active, and if it becomes active, present prompts to facilitate constructive. However, when it became interactive, I presented prompts to facilitate the active process and proceeded as illustrated in Figure 3.

Learner A : "**Peter** was bad at **math** and a **teacher** pointed out a lack of his **effort**."

	text	3 dimensions	cause	other	question	argument	reason
Passive							
Active	○	○	○				
Constructive		◎	◎				
Interactive		◎	◎	△	△	△	△

Figure 2. Example of Detection of Keywords and Relation between Keywords and ICAP. If there is one of three circles, active is. If there are two double circle, constructive is. If there are one of four triangles in addition to two of double circle, interactive is.

Active, constructive, and interactive prompts was made based on coding scheme of ICAP (Chi & Wiley, 2014). For example, we made "paraphrase the content of learning text" because active refers to paraphrasing leaning text. Also, we made "Explain why cause is classified in 3 dimensions" because constructive refers to deepening learning text. Furthermore, we made "explain one own idea by building on partner's contribution" because interactive refers to build on partner's contribution. Total number was 16 (active was 3, constructive was 5, and interactive was 8).

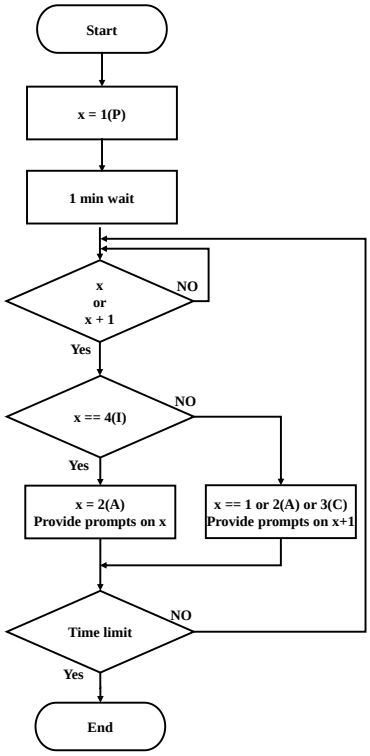

Figure 3. Flow Chart of Changes of ICAP States and Types of Facilitation Presented. Detection of keywords was conducted at all the time.

2.5 Dependent Variables

In this study, learning performance was used as the dependent variable. In the analysis, from the pre-test to the post-test, whether the score increased or not, it was divided, and the independence test was performed.

The rate of these test was rated by one coder. Rating was standardized as follows and conducted on a scale of 1 to 5 point is not correct/answer. 1 point is naïve but correct answer. 2 point is abstract answer based on learning text that include attribution theory. 3 point is answer based on learning text that include the causal attribution of success and failure in addition to that. 4 point is correct answer based on learning text that include 3 dimensions (internal-external, stable-unstable, controllability-uncontrollability) in addition to those. 5 point is specific answers deepened the learning text that include specific explanation in addition to those. The specific explanation is description using example and deep content based on the experimental task and learning text. Accordingly, learning performance measures the depth of understanding and knowledge on learning text and learners was needed to engage in interactive. Also, we calculated Krippendorff's alpha coefficient between first coder and second coder to investigate the reliability. As a result, the coder's matching rate was 0.48. Therefore, that the coding was reasonably reliable and the coding of first coder was adopted.

In addition to learning performance, we analyzed the ratio of new node exploratory (number of new nodes / total number of nodes in cooperation). The new node is related to the task. If added node was not related to the task, we didn't count. This makes it possible to easily confirm whether new knowledge or viewpoints are generated through the task.

3. Result

3.1 Concept Maps

We analyzed the concept map created in this task and confirm whether the performance of the task was affected between the conditions. Therefore, we calculated the ratio of new nodes (number of new nodes / total number of nodes in cooperation) and performed a one-factor analysis of variance. For example,

the number of new nodes of learner A in Figure 2 is 4, and the total number of nodes in cooperation is 10, so the ratio of new nodes is 40%. The number of new nodes of learner B is 5 and the ratio of new nodes is 50%. Figure 4 summarizes the average values of the new node ratios calculated in this way for each condition in Task 2. Thus, a difference was observed between the conditions (F (2,57) = 3.74, p <.05, *partial η2* = 0.12). As a result of multiple comparisons by Shaffer's method, it was found that the ratio of new nodes for learners of keyword conditions was higher than that of control conditions (p <.05). It is suggested that the effect of interventions that facilitate interactive process based on keywords was reflected in the task.

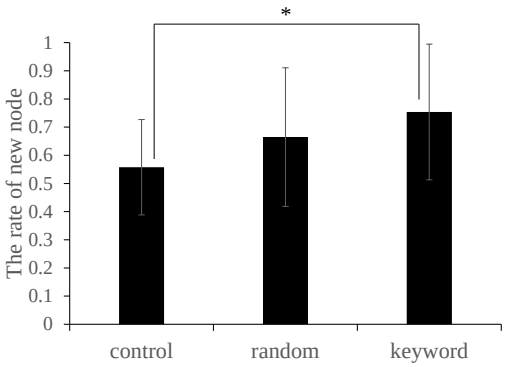

Figure 4. Comparison between the Conditions of the Ratio of New Nodes in the Concept Map in this Task 2. Error bars are the standard deviation and * represents p < .05.

3.2 Learning Performance

In this section, we analyze the learning performance to verify H1 and H2. Specifically, from the pre-test to the post-test, the score was classified into whether the score increased (with an increase) or not (without an increase), and Fisher's test was performed. Two factors (prompts presentation method) and learning performance were confirmed. Table 1 presents the cross-tabulation table. There was a significant difference between conditions with prompts and without prompts (p <.001). Next, as a result of the residual analysis, it was found that under the control conditions, there was a significantly lower increase and no increase was significantly higher. Under the keyword condition, an increase was significantly high, and no increase was significantly low. Furthermore, it was found that there was a significant increase in keyword conditions rather than in control conditions.

From the above, it can be said that H1 and H2 were partially supported because the keyword condition facilitated the learning performance more than the control condition.

Table 1. *Cross Table of Control Conditions, Random Conditions, and Keyword Conditions in Learning Performance*

	Without an increase	With an increase	Total
control condition	10 3.77 **	10 -3.77 **	20
random condition	3 -0.89	17 0.89	20
keyword condition	0 -2.88 **	20 2.88 **	20
Total	13	47	60

4. Discussion

In this study, H1 that the learner who presented the intervention facilitated the learning performance more than the learner who did not present the intervention, and H2 that the keyword condition facilitated the learning performance more than the random condition. From the results, H1 and H2 were partially supported. Therefore, it was suggested that the intervention that facilitates interactive process

based on context and timing using keywords is effective to some extent. However, between the learner's learning performance presented at random and the learner presented with prompts according to the context and timing, there was no evident difference.

Previous studies examining support for collaborative learning have revealed that more contextual and timing-based support is beneficial for learning (Walker, Rummel, & Koedinger, 2014). However, it has not been sufficiently examined whether developing prompts based on the collaborative learning process in this study and determining the presentation method facilitates learning. In previous studies, unlike this study, the learner's problem-solving process was modeled, and prompts were presented based on it (Walker, Rummel, & Koedinger, 2014), and the learner's line-of-sight pattern information was used to identify the learner's state. Studies have been conducted to detect the state and give feedback accordingly (D'Mello, Olney, Williams, & Hays, 2012). Therefore, in the future, it is necessary to respond to the context and timing more accurately, that is, to detect the learner's state and provide adaptive support (e.g., prompts) accordingly. However, it is highly useful to see the effect of the interventions responding to the ICAP-based keywords in this study.

We examined why there was no difference between the keyword and random conditions. Therefore, we used the log of keywords detected by the system under keyword conditions. The average number of changes from passive or active to interactive was 3.00 (SD = 1.95), the most change from passive to interactive was 6, and the least was 0. Also, we conducted an exact binominal test. Table 2 shows the number of learners who were from passive to interactive in order by using keyword that the prompt system detected. As a result, there was a significant difference between learners who were not from passive to interactive in order and learners who were from passive to interactive in order ($p < .05$). This result indicated that ICAP intervention based on context and timing was effective. However, some learners was not from passive to interactive.

Table 2. *The Number of Learners Who Were from Passive to Interactive in Order*

	Not from passive to interactive	From passive to interactive	Total
Keyword condition	4	16	20

The fewest pairs transitioned from the passive to the constructive process but stopped in the constructive stage from the beginning to the end. That is, it was suggested that some pairs in the keyword condition did not reach the interactive stage, and there was a problem in promoting changes from constructive to interactive. When the pairs with the most changes from passive to interactive were divided into learners, it was found that the learners who made statements about the interactive process were biased. Therefore, future support methods can be seen from the perspectives of cooperation and individuals. First, from the perspective of cooperation, when the system is stopped in the constructive stage, it is necessary to provide more enforceable support in the future, in addition to the prompts that facilitate the utterance of the ICAP used this time. For example, for the learner to refute the opinions of others, display the counter-argument input window and prompt them to input. By doing so, it is thought that conversations that are biased toward one's own opinions shift to an interactive state, in which opinions are constructed based on each other's ideas. From an individual point of view, it is necessary to separate the prompt presented according to each learner and the prompt presented according to the pair when presenting the prompt. This is because if the utterances related to the interactive process are biased, it is necessary to eliminate the bias and prevent it in learning outcomes in pairs. In the future, we will build a prompt presentation model from these two perspectives and examine how the interactive process is improved compared to this keyword condition.

In this study, we focused on learning performance, but as mentioned earlier, it is necessary to focus on the collaborative learning process and quantitatively analyze its depth. The study conducted this time is a rough analysis because the change was examined from the keywords captured by the system. Therefore, it is necessary to conduct a detailed analysis of how much the prompt that responds to the keyword could be facilitated the interactive process. Furthermore, it is necessary to confirm the effect of the support method by checking whether the ratio of the interactive process differs between the conditions. Therefore, in the future, we will focus on the collaborative learning process and examine its depth of the learning process.

5. Conclusion

It has been clarified that the learning process and related knowledge have deepened in the collaborative learning process. However, previous studies on prompt presentation in collaborative learning have not sufficiently examined the support method focusing on the deepening of the collaborative learning process of pairs of learners. In addition, when providing support, it is necessary to provide more relevant support in consideration of context and timing. Therefore, this study aimed to examine the effect of interventions to change collaborative learning process from the learner's utterance information based on the ICAP theory, focusing on the deepening of the learning process. To verify the effect of this intervention, we created prompts that respond to the utterance keywords defined based on each process defined as per the ICAP theory. When they were presented, we observed that learning performance was facilitated. In the experiment, we prepared a control condition that does not present prompts, a random condition that presents prompts randomly, and a keyword condition that prompts from passive to interactive in stages and conducted a laboratory experiment. As a result, it was found that the keyword presentation condition that facilitates interactive process based on conversation information facilitates learning performance more than the condition that does not present the prompts. In contrast, there was no difference in the conditions presented at random. Therefore, there was an effect of prompting from the passive to interactive process in stages to some extent. However, in this study, it is not possible to analyze in-depth the extent to which the change in the learning process can be facilitated. Therefore, a detailed analysis focusing on the collaborative learning process is necessary in future studies.

Acknowledgements

This work was supported by JSPS KAKENHI Grant Number JP20H04299.

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