A Computer-Supported Collaborative Learning Design for Quality Interaction

Masanori Yamada
Kyushu University

Yoshiko Goda
Kumamoto University

Hideya Matsukawa
Osaka University

Kojiro Hata
Otemae University

Seisuke Yasunami
Kumamoto University

Using the Community of Inquiry framework, this study investigated the interplay of computer-supported collaborative learning tools, psychological factors, and learning behaviors, with the goal of increasing active interaction among learners.

Community-based learning environments are gaining popularity, as educational organizations worldwide address the need to provide students with practical knowledge and skills—particularly 21st-century skills, such as critical-thinking skills, digital citizenship, and communication and collaboration. For years, researchers have studied computer-supported collaborative learning (CSCL) and applied it to various educational settings.

CSCL promotes cognitive change through group interaction and activities. The application of information and communication technology could be the center of effective learning environments for distributed, interactive, collaborative, and constructive learning and for learning assessment.1 The recent trend of using computer-mediated communication (CMC) tools, such as social media, for CSCL provides learners with opportunities to solicit and share knowledge while developing common ground with their peers and teachers. One key component in CSCL design is promoting active social interaction. Quality social interactions require a group atmosphere in which individuals share experiences and knowledge.[2] In assessing social media's role in learning settings, several studies have revealed the importance of social interaction, especially the relationship between the use of social cues and active interaction[3] and between social interaction and learning performance.[2] Overall, it appears that social interaction positively affects learning performance.

However, a learner's communication style factors into the role of social interaction in CSCL. To design effective CSCL, we need to investigate various psychological factors. The Community of Inquiry (CoI) framework, developed by D. Randy Garrison, is one of the referable concepts for enhancing the online learning community.[4] This framework can be used in designing and evaluating online collaborative learning environments.[5]

Our study's goal was to evaluate the effects of a CSCL system's functions on the promotion of active interaction in both formative and practical ways. We accomplished this by designing, developing, and evaluating a CSCL system that uses the CoI framework.

The CoI Framework

CoI is "an environment where participants collaboratively construct knowledge through sustained dialogue," which, through "opportunities to negotiate understanding," leads participants to develop their own "personal meaning."[4] The CoI framework consists of three elements:

- *Social presence* is "the ability of participants to identify with the community, communicate purposefully in a trusting environment, and develop interpersonal relationships by way of projecting their individual personalities."[4]
- *Cognitive presence* is the extent to which learners are able to construct and confirm meaning through sustained reflection and discourse.
- *Teaching presence* refers to the design, facilitation, and direction of cognition and social processes for

the purpose of realizing personally meaningful and educationally worthwhile learning outcomes.

CoI also provides an indicator for evaluating the learning environment and learning community, which leads to assessing the design used for collaborative learning. According to this indicator, the three types of presence in the CoI framework are expressive features, but social presence is also a perceived sense, based on research findings from the 1990s.[6] The other types of presence in the CoI also have perceived features.

J. Ben Arbaugh and his colleagues proposed the CoI psychological scale,[7] which enables the CoI's features to be evaluated from the viewpoints of both expressive and perceived features. They proposed that all three types of presence are expressive features that have perceived features. Two of us (Yoshiko Goda and Masanori Yamada)[2] then investigated the relationships among these three CoI elements in a bulletin board system, which is part of asynchronous CMC. The investigation revealed that teaching and cognitive presence correlated significantly with discussion satisfaction, and social presence associated positively with the number of utterances (postings). A few studies about the design and development of CSCL systems have also used the CoI framework.[5] Again, two of us (Yamada and Goda), along with N. Nishiyama, developed the collaborative learning system with the visualization function of social interaction based on the CoI framework, revealing the perceived effects on social-presence enhancement.[5] Fang-Wu Tung and Yi-Shin Deng investigated the effects of a CMC-based learning system for children, one designed from the viewpoint of social presence.[8] However, the latter two research projects did not evaluate the effects of social presence in terms of perception and behavior but pointed out the necessity of other functions for enhancing social and cognitive presence.

The CoI framework can be useful in designing and evaluating an online learning community. Two of us (Yamada and Goda) designed and developed a CSCL system for quality interaction using the CoI framework.[9] However, findings in previous research[5,8] did not mention the relationship between perceived psychological factors and learning behaviors, such as the promotion of social interaction and idea integration during online communication. Furthermore, these previous works did not suggest a design direction for effective CSCL, based on the CoI framework. One goal of our current study was to evaluate, both formatively and practically, the effects of CSCL functions on the establishment of social and cognitive interactions. Another goal was to suggest an effective design for CSCL.

System for CoI Enhancement

The CSCL system we developed has two main components: the chatbot and the concept map. These components can deepen students' cognitive engagement in discussions, because they were designed to organize learners' ideas and help them prepare for complex arguments. In-depth discussions require critical thinking, which increases the quality of interactions and supports the higher cognitive learning necessary for successful CSCL. The Socratic inquiry method, "one of the most popular and powerful teaching approaches that can be used to guide students in generating thoughtful questions,"[10] was shown to have positive effects on the development and maintenance of critical thinking in an online discussion setting.[10]

Accordingly, we developed the chatbot based on the computer program Eliza's adoption of the Socratic dialogue method (see Figure 1).[11] The chatbot-adopted Socratic inquiry method asks questions to guide learners in logical thinking, for example, "What is the reason for your idea?" as a reply to a learner posting "I think …." Thus, this study examined how the chatbot function affects cognitive learning as one of our research goals.

Figure 1. The chatbot interface implemented in the computer-supported collaborative learning (CSCL) system. Student's input and recorded chat with chatbot areas appear in the left pane.

The concept map function lets users chat with other group members while creating a concept map (see Figure 2). This function consists of two parts: a communication part on the left pane and an idea construction concept map on the right pane. Learners can post their ideas, "likes," and opinions; use emoticons (see Figure 3); and create relationships (for example, cause-and-effect relationships among posts). To create relationships, they click and drag a posted object from the left to the right pane and then create relationships among the posts, using arrows in the concept map. Learners can share the concept map with other learners. The concept map seems to raise learners' awareness of their peers' presence and cognitive learning behaviors.[12,13]

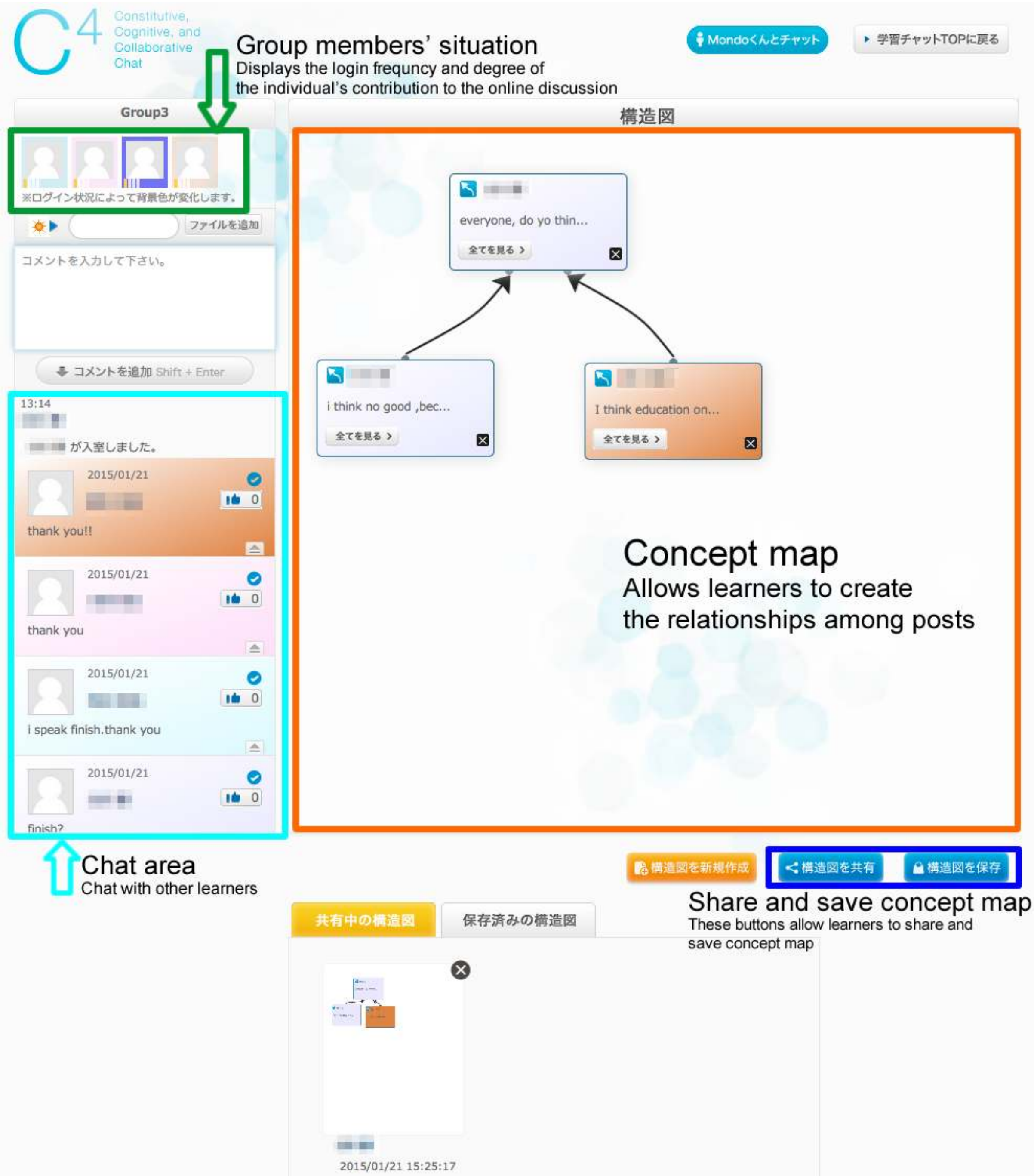

Figure 2. The interface of the chat and concept map functions in the CSCL system. A communication area appears on the left pane, and an idea construction concept map appears on the right pane. Learners can post their ideas, "likes," and opinions and create relationships.

Figure 3. The interface of the emoticon function and a message window. This appears in the chat area.

Our study consisted of two experiments: one formative evaluation using an experimental design in an in-class setting for a 90-minute class time (Experiment 1), and one practical evaluation including the out-of-class setting for a longer (one-week) duration (Experiment 2).

Experiment 1

The purpose of Experiment 1 was to investigate the effects of the CSCL system on the CSCL functions, the perceived social and cognitive presence, and the expressive social and cognitive presence indicators.

Participants and Procedure

Experiment 1's participants included 163 students (95 males, 68 females) at the same university. We carried out the experiment as an English class activity. The participants had to have minimal computer skills for participation (including word processing skills and email proficiency). They were required to participate in an online discussion during the class and discuss a given topic in English for 40 minutes.

To create an authentic context in which the participants could apply their previous knowledge and experiences, we set the discussion topic as "What do you think are the best ways to select better candidates for future university students?” The participants were randomly divided into four groups, each with four or five members: 37 participants had both a chatbot and a concept map, 43 had a chatbot without a concept map, 42 had a concept map without a chatbot, and 41 had neither the chatbot nor the concept map (that is, only the chat area was displayed). Those in the group with the chatbot but without the concept map were allowed to use the chat area for communication with other participants (a concept map was not displayed). The learners who used the chatbot were asked to first engage in a 10-minute conversation with it to deepen their ideas; the learners without the chatbot were asked to note their ideas on paper. Next, the learners were instructed to engage in an online discussion for 40 minutes, then answer a questionnaire.

Data Collection

The CoI questionnaire measured the participants' CoI level and learning behavior. Developed by Karen Swan and her colleagues[14] and shown in Table 1, the CoI survey consists of the three elements and 34 five-point Likert-scale items. We specifically examined social and cognitive presence, focusing on a learner-centered learning environment—the instructor did not participate in any online discussion in class. Therefore, we used the 21 items under social and cognitive presence and eliminated the items under teaching presence. The internal consistencies, reported with Cronbach's alpha (a measure of internal consistency, that is, how closely related a set of items are as a group), were 0.91 for social presence (SP) and 0.95 for cognitive presence (CP).[14]

Table 1. The Community of Inquiry framework.[14]

Category	Item
Teaching presence	1. The instructor clearly communicated important course topics.
	2. The instructor clearly communicated important course goals.
	3. The instructor provided clear instructions on how to participate in course learning activities.
	4. The instructor clearly communicated important due dates/time frames for learning activities.
	5. The instructor was helpful in identifying areas of agreement and disagreement on course topics that helped me learn.
	6. The instructor was helpful in guiding the class toward understanding course topics in a way that helped me clarify my thinking.
	7. The instructor helped keep the course participants engaged and participating in productive dialogue.
	8. The instructor helped keep the course participants on task in a way that helped me learn.
	9. The instructor encouraged course participants to explore new concepts in this course.
	10. Instructor actions reinforced the development of a sense of community among the course participants.
	11. The instructor helped focus the discussion on relevant issues in a way that helped me learn.
	12. The instructor provided feedback that helped me understand my strengths and weaknesses relative to the course's goals and objectives.
	13. The instructor provided feedback in a timely fashion.
Social presence1	14. Getting to know other course participants gave me a sense of belonging in the course.
	15. I was able to form distinct impressions of some course participants.
	16. Online or web-based communication is an excellent medium for social interaction.
	17. I felt comfortable conversing through the online medium.
	18. I felt comfortable participating in the course discussions.
	19. I felt comfortable interacting with other course participants.
	20. I felt comfortable disagreeing with other course participants while still maintaining a sense of trust.

	21. I felt that my point of view was acknowledged by other course participants.
	22. Online discussions helped me develop a sense of collaboration.
Cognitive presence	23. The problems posed increased my interest in course issues.
	24. Course activities piqued my curiosity.
	25. I felt motivated to explore content-related questions.
	26. I utilized a variety of information sources to explore the problems posed in this course.
	27. Brainstorming and finding relevant information helped me resolve content-related questions.
	28. Online discussions were valuable in helping me appreciate different perspectives.
	29. Combining new information helped me answer the questions raised in course activities.
	30. Learning activities helped me construct explanations/solutions.
	31. Reflection on course content and discussions helped me understand fundamental concepts in this class.
	32. I can describe ways to test and apply the knowledge created in this course.
	33. I have developed solutions to course problems that can be applied in practice.
	34. I can apply the knowledge created in this course to my work or other nonclass-related activities.

Using the CoI indicators (expressive SP and CP)[4] displayed in Tables 2 and 3, we evaluated the relationship between CoI elements and coded the students' comments regarding their utterances in the discussion activities to determine their learning behaviors. The instructor provided most of the feedback and intervention when meeting with the students in the classroom. The SP and CP of the CoI were the focus of asynchronous communication. There were three categories with 12 indicators for SP, and we adopted four categories for CP for coding. To increase credibility, the raters discussed inconsistent code assignments and reached agreement on all the comments. Garrison and his colleagues highlighted the importance of the unit of analysis for CoI coding.[4,15] For several years, researchers used the sentence as the unit of analysis[16] because the comments indicated more information, but this level of detail made encoding procedures more complicated and interpretation much more difficult.

Table 2. Social presence indicators.[15]

Category	Indicator	Definition
Interpersonal communication	Affective expression	Conventional or unconventional expressions of emotion, such as repetitious punctuation and emoticons
	Self-disclosure	Presenting biographies and details of life outside class or expressing vulnerability
	Use of humor	Teasing, cajoling, irony, understatements, sarcasm
Open communication	Continuing a thread	Using the reply feature rather than starting a new thread
	Quoting others' messages	Using software features to quote another's message in its entirety or cutting and pasting selections from others' messages
	Referring explicitly to others' messages	Direct references to contents of others' posts
	Asking questions	Asking questions of other students or the moderator
	Complimenting, expressing appreciation	Complimenting others or the contents of others' messages
	Expressing agreement	Expressing agreement with others or the content of others' messages

Category	Indicator	Definition
Interpersonal communication	Affective expression	Conventional or unconventional expressions of emotion, such as repetitious punctuation and emoticons
Cohesive communication	Vocatives	Addressing or referring to participants by name
	Addressing or referring to the group by using inclusive pronouns	Addressing the group as “we,” “us,” “our,” and so on
	“Phatics”(sic) (greetings, salutations)	Communication that serves a purely social function: greetings and closures

Table 3. Cognitive presence indicators.[15]

Phase	Indicator	Description
Triggering event	Evocative (inductive)	Recognize problem Puzzlement
Exploration	Inquisitive (divergent)	Divergence Information exchange Suggestions Brainstorming Intuitive leaps
Integration	Tentative (convergent)	Convergence Synthesis Solutions
Resolution	Committed (deductive)	Apply Test Defend

Results

We analyzed the students' perceptions and utterances about social and cognitive presence. Three learners dropped the class, so we had 160 students from the Pharmacy Department and Physical Science Department complete the questionnaire and take part in the online discussion. Table 4 shows the average total score for each presence (and its standard deviation in parentheses) in each group, and Table 5 shows each group's average number of utterances (and their standard deviations). The reliabilities (Cronbach's alpha) for each presence were 0.81 for SP (9 items) and 0.91 for CP (12 items). Each reliability value was statistically acceptable, owing to scores over 0.8.

Table 4. Average total scores on the CoI questionnaire (social and cognitive presence) in Experiment 1 for the four groups.

Group	Chatbot	Concept map	Perceived social presence* (SD)	Perceived cognitive presence† (SD)
1	Yes	Yes	29.68 (5.47)	41.15 (8.43)
2	Yes	No	29.63 (5.17)	42.21 (8.32)
3	No	Yes	29.62 (6.76)	41.24 (7.24)
4	No	No	30.34 (6.59)	42.37 (9.47)

* The minimum is 9; the maximum is 45

† The minimum is 12; the maximum is 60

Table 5. Average number of utterances in each presence for the four groups.

Group	Chatbot	Concept map	Expressive social presence (SD)	Expressive cognitive presence (SD)
1	Yes	Yes	8.35 (5.09)	6.56 (6.63)
2	Yes	No	12.02 (11.83)	6.98 (6.35)
3	No	Yes	7.62 (6.30)	5.69 (4.17)
4	No	No	10.95 (9.41)	4.51 (3.32)

Path analysis

We conducted a path analysis using the Stata 13 statistical package to determine the relationships among functions, perceived factors, and expressive factors. We used dummy variables to differentiate the functions used. We set the "chatbot" variable to 1 when the chatbot was available and 0 when it was not, and did the same for "concept map." We used the total score of the SP and CP questionnaire items and the total number of SP and CP utterances as observation variables for this analysis. Figure 4 shows the path model of these relationships. The chatbot had positive effects on the enhancement of expressive cognitive presence.

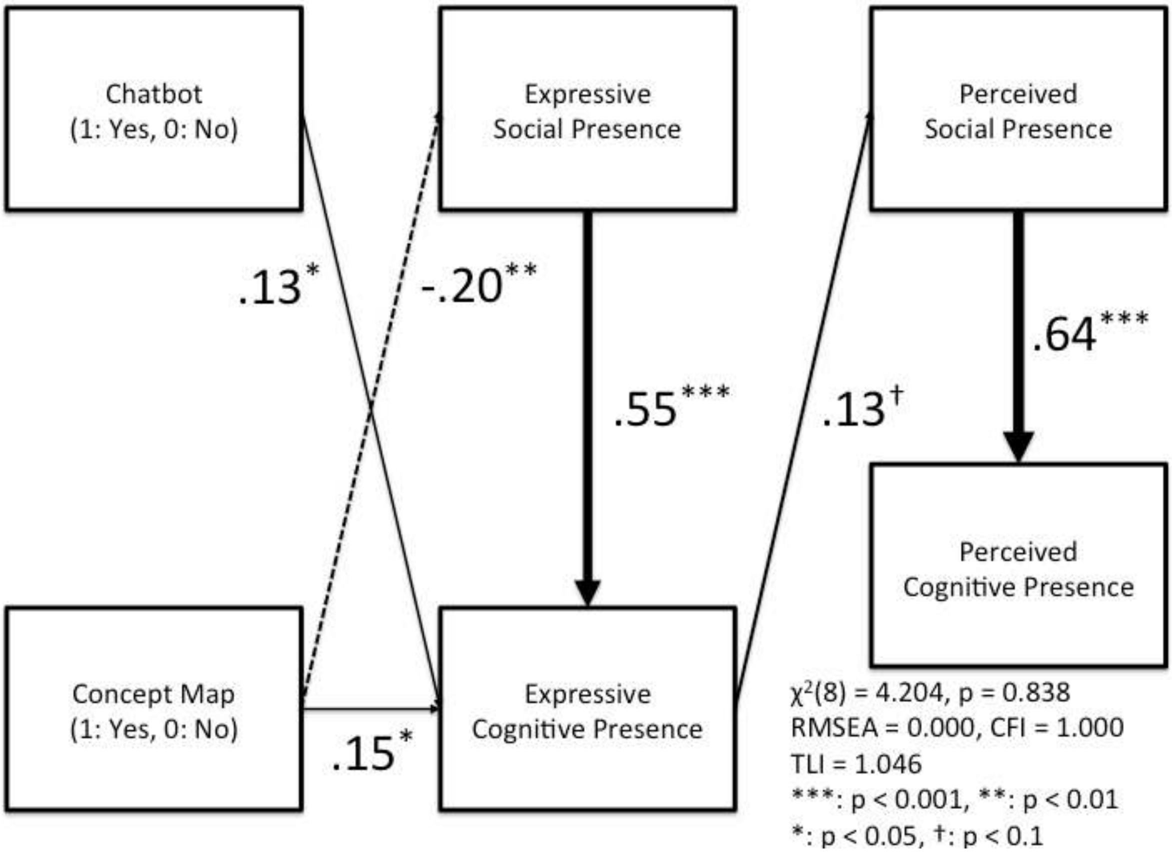

Figure 4. Path model of the relationships among functions, perceived factors, and expressive factors. The dotted line means a negative relationship.

On the other hand, the concept map had significant negative effects on the enhancement of expressive social presence but positive effects on that of expressive cognitive presence. Expressive social presence was effective in enhancing expressive cognitive presence. Expressive cognitive presence promoted the perception of social presence; then it led to the enhancement of cognitive presence. Thus, the CSCL functions supported the promotion of cognitive learning in the online learning community.

Discussion

One possible reason the concept map had a negative effect on the enhancement of expressive social presence was that it allowed users to focus on constructing their own ideas without sharing the concept map function, which was cognitive learning behavior. One of the features of social presence is socioemotional communication (for example, using emoticons). Thus, the concept map seemed to reduce opportunities to create a social atmosphere during online discussions. However, previous research showed that the concept map allowed the learners to confirm other learners' presence, so when the effect of the concept map is discussed, both creating the concept map alone and sharing the concept map with other learners should be considered. In this research, these two were not discriminated, which might cause the negative effect of the concept map for communication. Another reason was that the learners who did not use the concept map seemed to confirm the other learners' presence through communication.

The chatbot, which also allowed the users to construct their own ideas during communication, had a positive effect on expressive cognitive presence. This might be because the chatbot function enhanced their readiness to communicate with group members. Cognitive tools of this type might provide important means for enhancing active discussion.

Expressive cognitive presence had a slightly positive effect on perceived social presence and an indirect effect on perceived cognitive presence, which means that perceived social presence mediated between expressive and perceived cognitive presence. Several expressions, such as the question and statement of a stance, are concerned with both social and cognitive presence; therefore, expressive cognitive presence can lead to the enhancement of perceived social and cognitive presence.

The use of tools in online learning can affect the enhancement of cognitive presence; on the other hand, social presence seems to be enhanced by group cohesion.[17] The results of Experiment 1 revealed the main and interaction positive effects of the chatbot and the concept map on enhancing social interaction in the experimental setting for the formative evaluation. To enhance social presence, the effects of the functions to support group cohesion should be investigated in a practical setting.

Experiment 2

Experiment 1 showed the relationships between the functions and CoI elements in terms of the differences with and without the functions as a formative evaluation. The research findings based on the comparison between the plain chat without the chatbot or the concept map revealed that the CSCL functions enhanced active interaction among the learners and promoted the perception of CoI elements. Therefore, in Experiment 2, we employed a design of the collaborative learning activities suggested by Experiment 1's findings and examined the effects of the CSCL with the chatbot and the concept map in a practical setting for a longer duration.

Participants and Procedure

Experiment 2 involved 134 university students of pharmacy and architecture, engaged in an English class activity. The instructor explained the assignment for the next class at the end of each class. The English discussion theme was "What is the ideal entrance examination?" We randomly divided the students into 33 groups (four learners per group for 31 groups and five learners per group for two groups) and asked them to engage in this discussion using the system until the next class (that is, for one week).

Data Collection

We used the same methods as those in Experiment 1, adding two items to the questionnaire. One asked about the participants' satisfaction with the online discussion (five-point Likert scale), and the other asked about their perceived sense of self-contribution to the online discussion (range: 0–100), in order to understand the learners' perception of online learning out of class. To investigate the relationships between the functions and the perceived data, we counted the number of learners' postings in the chatbot, the number of objects in the concept maps, and the number of "likes."

Results

We analyzed the students' perceptions and utterances about social and cognitive presence. Out of the 134 students, 110 answered the questionnaire. Tables 6 and 7 display the descriptive data.

Table 6. Average total scores (social and cognitive presence) on satisfaction with and perceived sense of self-contribution to the English online discussion.

	Average total score	SD
Perceived social presence (range: 9–45)	30.47	5.39
Perceived cognitive presence (range: 12–60)	39.04	8.54
Satisfaction (five-point Likert scale)	2.50	0.70
Contribution (range: 0–100)	32.4	23.59

Table 7. Average total score on expressive social and cognitive presence for the numbers of postings in the chatbot, objects in the concept maps, and "likes."

	Average total score	SD
Expressive social presence	7.58	6.90
Expressive cognitive presence	2.74	5.11
Number of postings in chatbot	7.50	6.94
Number of objects in concept map	1.09	2.05
Number of “likes”	2.85	5.63

Path Analysis

In Experiment 2, we also conducted a path analysis using Stata 13 to investigate the relationships among function use, psychological perceptions, and utterances about social and cognitive presence as the learning behaviors in the learning community. Figure 5 illustrates the path model showing these relationships.

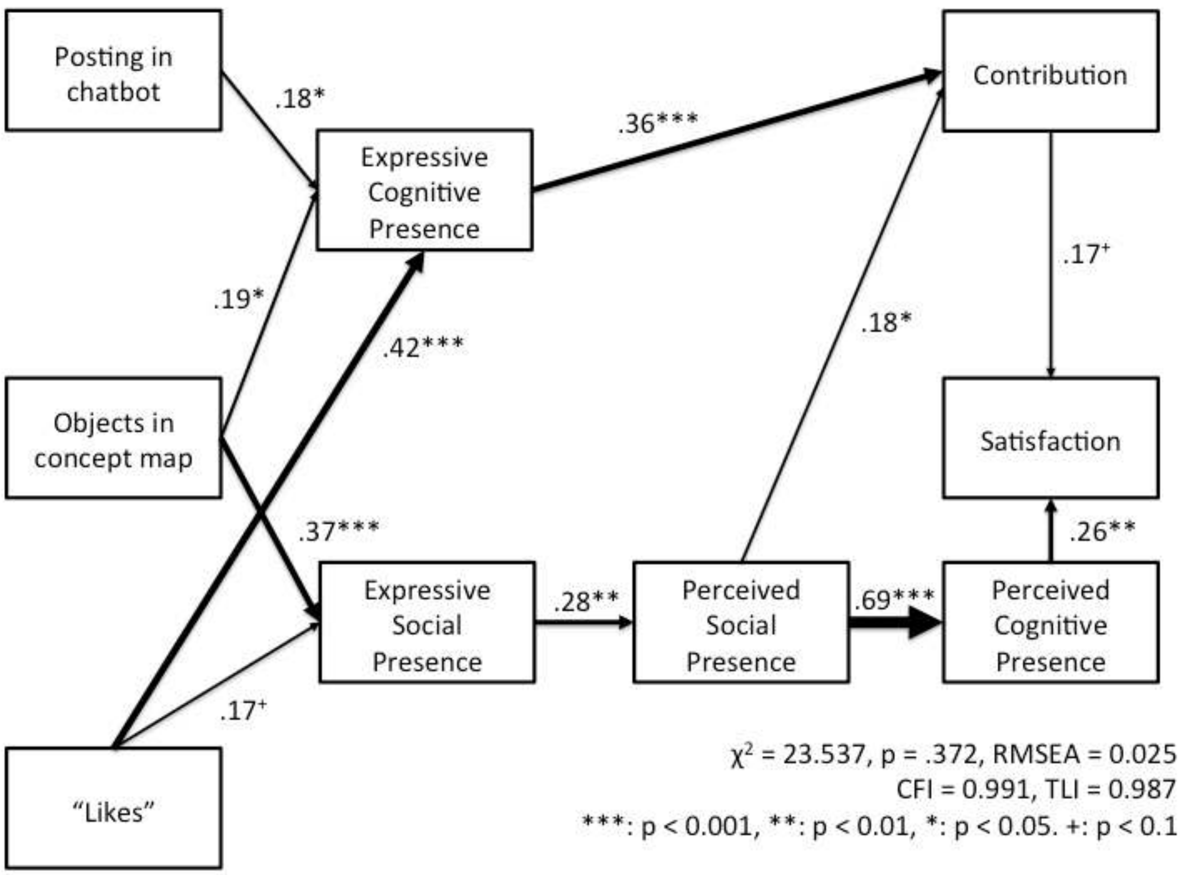

Figure 5. Path model of the relationships among function use, perceived and expressive presence, perceived contribution, and satisfaction with the online discussion in the collaborative learning environment.

The indicators showed that the model was acceptable. All relationships between the variables were positive. The model indicated that the chatbot was effective for expressive cognitive presence, and the number of objects created by the learners in the concept maps determined the strength of both expressive social and cognitive presence. The number of “likes” also had direct effects on the enhancement of expressive social and cognitive presence. The path analysis did not confirm a significant relationship between expressive social and cognitive presence.

Expressive social presence had significant effects on the enhancement of perception of social presence, and expressive cognitive presence enhanced the perceived sense of contribution to the online discussion, which promoted satisfaction with the online discussion. Perceived social presence also enhanced the perceived sense of contribution. Furthermore, perceived social presence was the only variable that promoted the perception of cognitive presence, which in turn had directly enhanced satisfaction with the online discussion.

Discussion

The results showed that frequent use of the chatbot enhanced expressive cognitive presence but not expressive social presence. These results differed from those of Experiment 1, which indicated that the system with the chatbot enhanced expressive social presence. In Experiment 2, under the condition that the chatbot was available to all learners, the learners had an opportunity to deepen their thoughts on the topic in English and be ready for English communication with other learners, and the high frequency of using the chatbot promoted active discussion, meaning that the chatbot affected critical thinking.

The use of the concept map showed negative effects on expressive social presence in Experiment 1. However, in Experiment 2, under the condition that all learners could use the concept map, the high number of objects in the concept map had a significant positive relationship with expressive social and cognitive presence. The concept map is a cognitive learning tool,[12] but it also enhances expressive social presence. This result supports earlier findings,[5] which showed that concept maps promote communication among learners when combined with a chat tool. That research also indicated that concept maps could enhance group cohesion and promote learners' mutual understanding of one another's thoughts, due to the visualization feature.[5]

The number of "likes" was effective for both expressive social and cognitive presence. "Likes" meant that the other learners read the posts and acknowledged each person posting as a group member. This feature was one of the subitems of social presence, categorized into "group cohesion." The "liked" posts seemed key to the active discussions; therefore, they led to the enhancement of expressive cognitive presence.

Experiment 2 did not demonstrate a significant relationship between expressive social and cognitive presence, although Experiment 1 did. In Experiment 1, expressive cognitive presence led to the enhancement of perceived social presence, but Experiment 2 did not show a significant relationship between them, given that expressive cognitive presence only led to the perceived sense of contribution to the online discussion.

The path analysis in Experiment 2 included two psychological variables. Therefore, we could not simply compare the results of Experiments 1 and 2, but these indicated that each expressive and perceived presence had multiple relationships with perceived contribution and satisfaction, though not a linear relationship, as Garrison indicated.[4] Some variables seemed to mediate between social and cognitive presence. In Experiment 2, the perceived sense of contribution could mediate and explain the variable of each presence.

This research found that the functions for enhancing social and cognitive presence—not only the communication tools used (such as the concept map and "likes") but also those used before the online discussion (such as the chatbot, which prepared them for online discussion)—contributed to active online learning. Many previous studies have indicated the effects of cognitive tools such as concept maps, visualization tools, and information-sharing tools. Recent research has focused on the design and effects of the functions that promote social interaction among learners, because social media has become so popular in educational settings all over the world.

The CoI framework is a useful framework for evaluating learning activities and behaviors in the learning community; however, few studies have referred to it in relation to effective CSCL design. Our findings can contribute to effective CSCL design and class design with the use of social media, such as Facebook.

However, this research had several limitations. First, its two experiments were conducted in English classes. The participants' consciousness might have focused on grammatical accuracy in communication, not the discussion theme, although we set the theme from the viewpoint of the learners' background knowledge. Second, we did not investigate the relationship between the CoI design and learning performance. Our research revealed the relationship between the CSCL design, based on the CoI framework, and active interaction in online discussion, but the time period was insufficient for investigating the relationship with learning performance.

Further research is needed to examine the relationships among system use, psychological factors, and learning performance. Longitudinal research is necessary to conduct the research from the perspective of learning performance. We should also add more functions, such as making the system available in a mobile environment. Several learners pointed out that they could learn more if the system worked on mobile devices. Mobile devices seem to influence the immediacy of active online discussions, and immediacy plays an important role in enhancing perceived social presence.[18] Therefore, we should modify the system to improve collaborative learning.

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Masanori Yamada is an associate professor in the Faculty of Arts and Science and the Graduate School of Human-Environment Studies at Kyushu University. His research focuses on educational technology, especially computer-mediated communication systems for collaborative learning based on psychological theories. He received his PhD in human system science from Tokyo Institute of Technology. Contact him at mark@mark-lab.net.

Yoshiko Goda is an associate professor in the Research Center for Higher Education and Instructional Systems program in the Graduate School of Social and Cultural Sciences at Kumamoto University, Japan. Her research interests include self-regulated learning and learning support for e-learning, online education program evaluation, and innovative community for global education. She received her PhD in science education at Florida Institute of Technology. Contact her at ygoda@kumamoto-u.ac.jp.

Hideya Matsukawa is an assistant professor in the Center for Education in Liberal Arts and Sciences at Osaka University. His research focuses on educational technology—in particular, educational data mining. Matsukawa received his PhD in human sciences from Osaka University. Contact him at hideya@celas.osaka-u.ac.jp.

Kojiro Hata is an associate professor in Faculty of Social and Management Studies at Otemae University. His research focuses on educational technology—in particular, learning management systems. Hata received his PhD in engineering from Osaka University. Contact him at k-hata@otemae.ac.jp.

Seisuke Yasunami is an associate professor in the Division of Curriculum Development at the Research Center for Higher Education, Kumamoto University. His research interests include computer-assisted language learning, teaching based on the concept of English for specific purposes, English learning materials development, learner autonomy, and effective use of learning management systems. Yasunami received his MA in English literature from the Graduate School of Kumamoto University. Contact him at yasunami@kumamoto-u.ac.jp.

This study investigated, through both formative and practical evaluation, the relationships among the use of functions in computer-supported collaborative learning (CSCL), psychological factors, and learning behaviors related to applying the Community of Inquiry (CoI) framework. The goal was to increase active interaction among learners. In two experiments inside and outside the classroom, the authors examined an online discussion and collected data using questionnaires that assessed perceived psychological factors, as well as communication logs related to the efficacy of CoI. The results of a path analysis showed two points. First, cognitive learning tools support the enhancement of expressive cognitive presence that promotes the perception of CoI as formative evaluation. Second, the frequency of the use of the functions fostered expressive social and cognitive presence (which enhanced the perception of both), perceived contribution, and satisfaction with online discussion. This article is part of a special issue on social media for learning.