A Shareable Whiteboard System for Distance Collaborative Learning which Enables Instruction for Multiple Groups of Students

Yuichi OHKAWA[a*], **Kazuki WATANABE**[a] **& Takashi MITSUISHI**[a,b]

[a]*Graduate School of Educational Informatics, Tohoku University, Japan*
[b]*Center for Information Technology in Education, Tohoku University, Japan*
*kuri@ei.tohoku.ac.jp

Abstract: In order to help collaborative learning with multiple groups of students participating over a network, we developed a shareable whiteboard system that allows a teacher to observe multiple groups simultaneously and provide instruction to specific groups directly. Through an analysis of log files and video recordings, obtained from an experimental lesson, we investigated the effectiveness of the proposed system. Based on these records and a questionnaire survey, we found the proposed system to facilitate the implementation of collaborative learning over a network.

Keywords: Computer-Supported Collaborative Learning, Distance Learning, Collaborative Learning, Shareable Whiteboard

1. Introduction

Collaborative learning—based on the premise of communication among students—is a method of knowledge acquisition that is more effective than conventional learning methods by teacher centered didactic teaching. Therefore, collaborative learning is currently being actively implemented in various educational institutions (e.g., Sugimoto *et al.*, 2002; Kaneko *et al.*, 2007). In addition, collaborative learning using a whiteboard, which is one form of collaborative learning, is expected to facilitate discussions and develop students' imaginations, because students can discuss their ideas using graphics (Obata, 1998; Kobayashi, 2002). Therefore, many past studies have attempted to implement distance collaborative learning using a whiteboard through a network (e.g., Gall and Hauck, 1997). However, there remain several problems that must be solved if we are to successfully implement collaborative learning using a whiteboard through a network.

In order to perform effective collaborative learning, it requires that multiple students participate in the collaborative learning activities. Typically, for these activities, students are divided into multiple groups. When learning begins, the teacher, who oversees the collaborative learning process, needs to simultaneously observe the activities of multiple groups of students and must grasp the progress of each group. Conventional collaborative learning is implemented in one location itself, and the teacher can move among the different groups of students; in this situation, it is not difficult for a teacher to watch the students' learning. However, distance collaborative learning is implemented over a network, in different locations; therefore, it is more difficult to observe multiple groups simultaneously. In addition, teachers may need to intervene in students' activities, either instructing them or imparting advice to specific groups or all groups, as required.

In order to overcome these problems, Koga *et al.* (2002) developed a system by which students can exchange their opinions using text chat and a drawing editor; using this, the teacher is also able to observe the students' learning processes. However, in this system, it was difficult for teachers to observe multiple groups of students simultaneously, since the teachers had to run as many client systems as there were groups. On the other hand, Matsuuchi *et al.* (2010) developed the TERAKOYA learning system according to which the teacher can share his/her screen with the students using an electronic blackboard. Through this system, the teacher was able to intervene in the students' activities. However, this system was not developed for collaborative learning with multiple groups.

In order to achieve an effective collaborative learning system with multiple groups of students over a network, in this study, we developed a shareable whiteboard system using which the teacher could observe multiple groups simultaneously and provide instruction to students. In this paper, we describe the results of an experimental lesson conducted using the proposed system.

2. Intended collaborative learning styles and requirements

2.1 Collaborative learning

The type of collaborative learning targeted in this study is that which can be implemented from remote locations over a network. Students will be divided into multiple groups, and during the learning process, they will draw their ideas on a whiteboard, which will be arranged for each group. Students belonging to the same group will share the ideas they have drawn on the whiteboard. Moreover, they will be able to modify their drawn ideas by exchanging opinions. Then, as a group, they will arrive at a single idea.

The learning activities are aimed not only at knowledge acquisition in a given subject but also at the development of the skills of idea creation and communication.

2.2 System requirements

The system proposed in this study aims to help collaborative learning with multiple students from different locations over a network. Therefore, one of the requirements of the system is that it should be able to divide students into small groups. The system should also be equipped such that students can draw their ideas on the whiteboard; the drawn ideas should then be shared among members of the same group, and the students should be able to exchange opinions regarding these shared ideas.

With regard to the teacher, the system should enable him/her to observe multiple groups simultaneously and provide instruction to each or all groups. We determined that a total of 36 students (6 groups × 6 students) would be using the proposed system at the same time, which is the maximum number of students one teacher can instruct, based on the premise that the proposed system will be used for higher education.

3. Related studies

We surveyed related studies that aimed at collaborative learning using a shareable whiteboard. We also surveyed previous studies that had used shareable whiteboard systems not only for collaborative learning but also for electronic meetings.

As stated above, Koga *et al.* (2002) developed a collaborative learning support tool for use in distance learning. According to their system, learners can use a drawing editor and text chats to exchange ideas. On the other hand, the teacher can observe and monitor the activities of the learners according to a learning process model that prepared by the teacher beforehand. However, the drawback to this system was that it was difficult to use with multiple groups. Matsuuchi *et al*. (2010) developed the TERAKOYA learning system, a support system for interactive teaching using a shareable whiteboard. This system can transmit pictures and figures drawn by a teacher onto the screens of students' PCs, and the students can make notes on this screen. In addition, the teacher can even write on the students' screens directly. However, this system does not support a collaborative learning scenario that involves multiple groups of students; further, with the TERAKOYA learning system, students cannot hold discussions with others, view each other's screens, or write on their screens. Ito *et al*. (2003) proposed a support system for cooperative working. It allows students to draw pictures on a whiteboard and view texts as the object of the whiteboard linking to the pictures. This system also has a function to output a log in which texts and pictures are recorded along timeline so that students can reflect on their activities after a lesson. However, this system is also not intended to be used for a collaborative learning environment that involves multiple groups. Moreover, this system is not equipped with the function of allowing teachers to intervene in their students' activities for the purpose of delivering instruction. Suzuki *et al*. (2013) developed "edutab," a support system for remote teaching. This system targets for the teaching of the Japanese language in elementary schools. Using this system, a teacher can display texts and pictures on

students' client systems, and students can write on the screens of their clients. The teacher can view the screens of multiple clients at one time and write on the screen of any client, when needed. However, since this system was not designed for collaborative learning, it is not equipped for communication among students. Roseman *et al.* (1996) developed a groupware tool called "TeamRoom." This tool creates virtual rooms in which users can hold meetings from remote locations. Users can also display pictures and text messages and can write on their screens. However, since this tool was not intended to use for the educational purpose, it does not have functions to observe students' activities can be observed across multiple virtual rooms.

4. A system for collaborative learning among multiple groups

4.1 Framework of the proposed system

In order to implement collaborative learning for multiple groups over a network, we are proposing the following system with a shareable whiteboard. Figure 1 shows the framework of the proposing system.

In order to allow a teacher to instruct multiple students in collaborative learning with a shareable whiteboard over a network, our system consists of three sub-systems: (1) a client system for students, which has a whiteboard with multiple pages that students can use for learning; (2) a client system for the teacher, which the teacher can use to observe and instruct students; (3) a server system, using which the teacher and students' client systems communicate with others. We show each sub-system below.
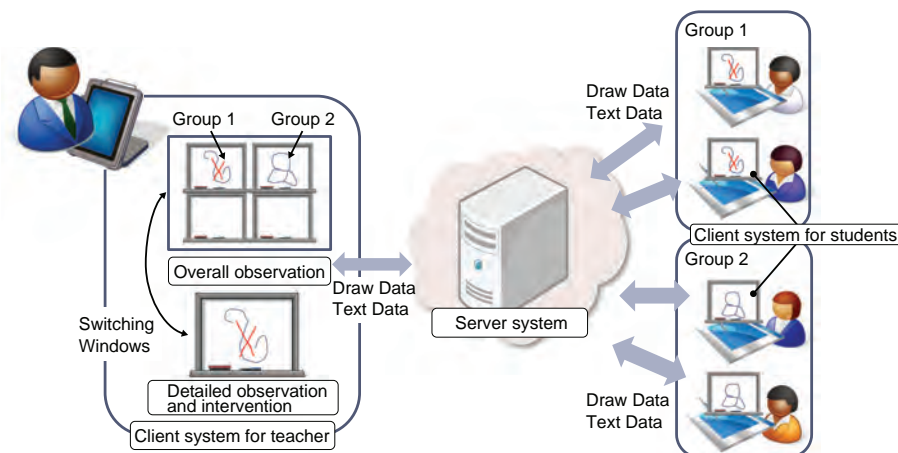

Figure 1. Framework of the proposed system

4.2 A client system for students

The client system for students is equipped with functions for a shareable whiteboard, text chat, and the facility to call the teacher. Figure 2 shows a screenshot of the client system for students, which runs on Microsoft Windows system.

Figure 2. Client system for students

A shareable whiteboard is requisite for students to discuss ideas with members of the same group. Members of the same group share their content on the whiteboard by drawing in the whiteboard area of the client system using specified colors and thicknesses. In addition, the whiteboard has multiple pages that can be turned by clicking on the forward and back buttons. Although the content on each page is shared among members of the same group, as previously described, each page can also be used as a personal space that students can draw on if other members of the group do not use this space. Students of the same group use the text chat function to exchange opinions. Messages—which are inputted by a student into the text box at the lower right-hand side of the client system—are displayed on screens of the other members. Moreover, this chat display can also contain messages from the teacher and other system messages. To distinguish between messages, they are categorized according to color. Therefore, in this system, the teacher can accurately observe and watch the students' learning progress. However, in the case of too many groups, the teacher will not always be able to gather detailed information on the progress of all the groups. If the students have questions to ask the teacher, they can click on the "teacher icon" at the upper right-hand side of the client.

4.3 A client system for teachers

In collaborative learning, it is important for the teacher to provide appropriate instruction to the students; therefore, our client system had the following functions for teachers: the teacher can (1) observe multiple groups of students simultaneously (overall observation); (2) observe individual groups in detail (detailed observation); (3) intervene in the whiteboards of arbitrary groups; (4) manage the members of all groups.
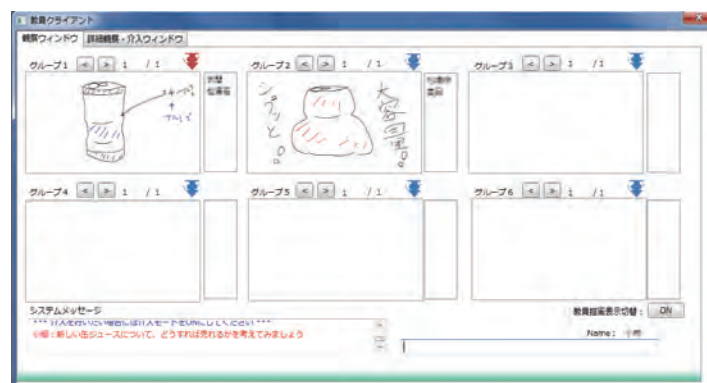

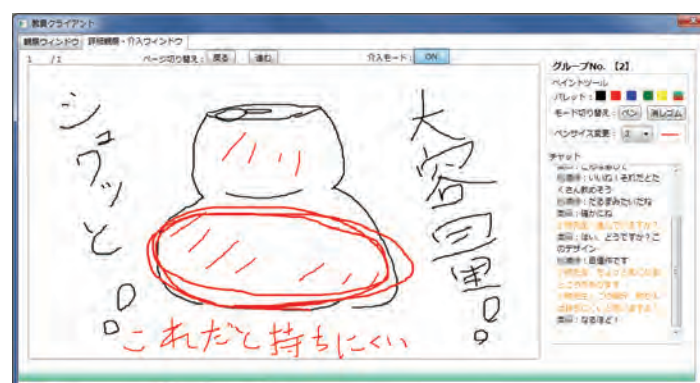Figure 3. Client system for teachers: an interface for overall observation

Figure 4. Client system for teachers: an interface for detailed observation and intervention

Figure 3 shows the teacher's interface for viewing multiple groups at the same time (overall observation). As shown in this image, the teacher can observe multiple groups simultaneously by looking at small-sized versions of all the groups' whiteboards in one window. Moreover, the teacher can observe by turning the pages of the whiteboard when there are students who draw on different pages.

The functions for detailed observation and intervention, as shown in Figure 4, enable the teacher to observe a full-scale whiteboard and chat display that are not displayed in the "overall observation" window. The teacher can also provide instruction to students by writing directly on the whiteboard or in

the chat boxes, as necessary. Moreover, if the teacher wants to select one particular group to impart instruction, he/she can click on the reduced-size whiteboard for that group. The management function allows the teacher to manually divide students into groups.

5. The experiment

In order to investigate whether collaborative learning can be implemented using our proposed system, we conducted an experimental lesson.

5.1 The experimental lesson and evaluation methodology

The duration of the experimental lesson was set to 100 minutes, with an interval of 10 minutes between the first and second halves, which were 45 minutes each. The participants comprised five Japanese undergraduate or graduate students in their 20s, with experience in operating PCs. The role of the teacher was played by one of the five participants, who had taken a course in teacher training. The remaining four participants played the role of the students. Taking into consideration the environment suitable for collaborative learning over a network, the participants were assigned to separate rooms to avoid interference, as shown Table 1. A screen separated participants who happened to be placed in the same room. In addition, we made the participants use earphones. To allow students to converse with members of the same group, we set up their PCs with Skype before the experiment. Therefore, students were able to communicate with members of their group through three modes: text chat, the whiteboard of the proposed system, and Skype. To allow the teacher to conduct lessons, we also configured the students' PCs with Ustream, which would deliver video streaming from the teacher. We also equipped the teacher's PC with Skype, in case it was required. Therefore, the teacher could use four modes of communication by which to intervene in the students' activities: text chat; the whiteboard, equipped with the detailed observation function; Skype; and Ustream, which was used for the simultaneous distribution of information. We explained our proposed system to the participants and conducted a trial session in order to make any necessary adjustments to the system before the actual experiment could begin. The entire experiment was recorded by video.

Table 1: Arrangement of rooms and participant grouping

Participants	Teacher	Student A	Student B	Student C	Student D
Assigned Group	—	Group 1		Group 2	
Room	Room 1	Room 2	Room 3	Room 2	Room 3

The subject of the experimental lesson was "an examination of new package designs for drinks." We planned the experiment with the aim of enabling students to understand that cooperation with other members of the same group is essential by giving them the goal of building a one design; students had to realize this goal by sharing information with each other voluntarily, using the predetermined channels. In order to promote its activities, we confirmed whether the teacher was able to observe the students' activities and provide support. The first 30 minutes of the experiment consisted of the teacher's
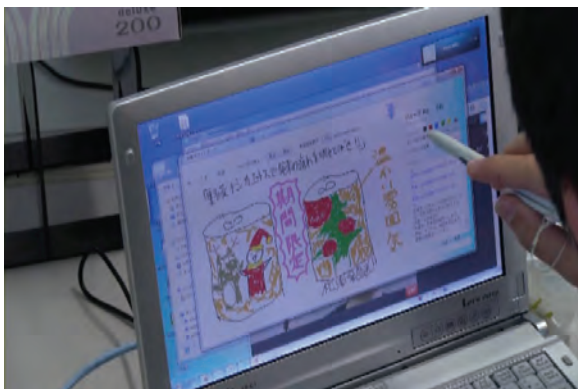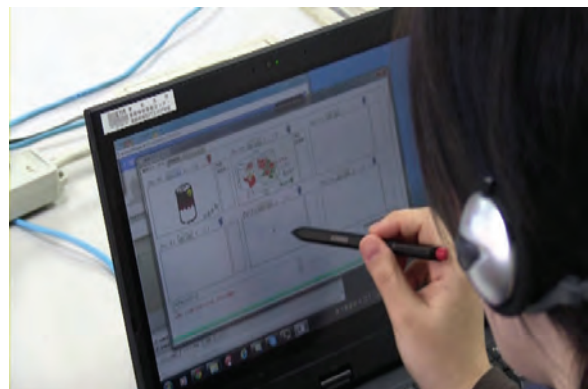

Figure 5. A student using the proposed system

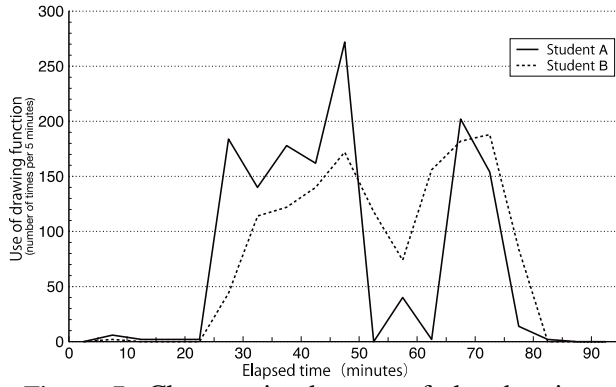Figure 6. The teacher using the proposed system

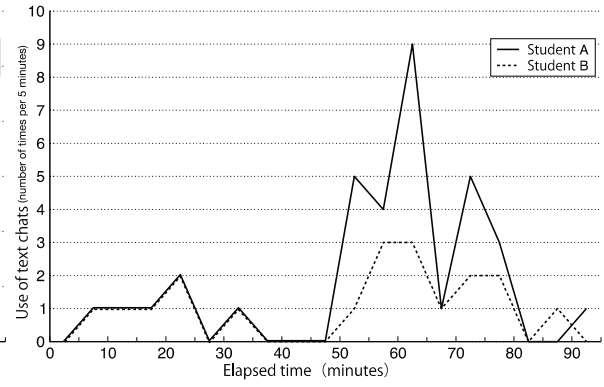**Figure 7**. Changes in the use of the drawing function in Group 1

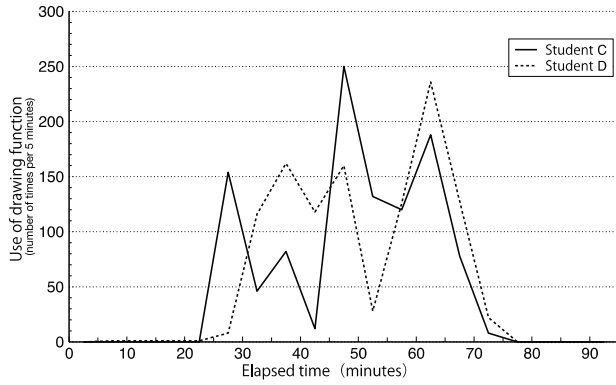**Figure 8**. Changes in the use of text chats in Group 1

Figure 9. Changes in the use of the drawing function in Group 2
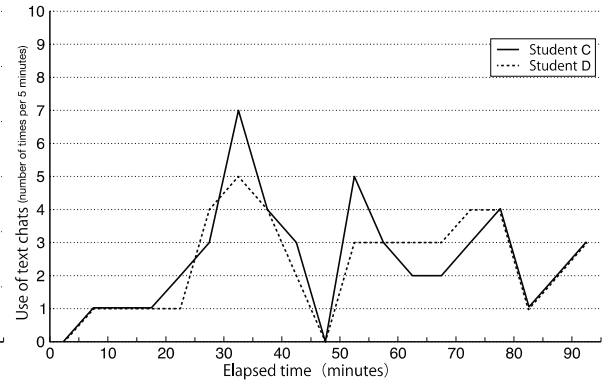

Figure 10. Changes in the use of text chats in Group 2

explanation of premise knowledge for the subject over Ustream. In the next 15 minutes, the students had to draw their ideas on the whiteboard. In the second half of the experimental lesson, 35 minutes were assigned to the students for discussions and for organizing their ideas to arrive at one final idea for the group. In the final 10 minutes, the teacher provided comments and feedback to each group over Ustream. Figure 5 and 6 are pictures of the participants using the system.

In order to evaluate the proposed system, we distributed a questionnaire after the experiment and identified different types of behavior exhibited by the participants at varying times during the experiment by comparing log files with the video recordings. The questions in the questionnaire were based on the following categories (for students): whether the students used the proposed system as a communication tool; whether the students were conscious of the teacher's presence at all times; (for the teacher) whether the teacher could support the students' learning progress by using the functions of overall observation, detailed observation, and intervention; and whether the teacher could impart teaching smoothly. The questions in the questionnaire had a five-point evaluation as well as multiple-choice options; participants were also requested to insert free descriptions.

5.2 Results and evaluation

5.2.1 Behavior of the participants

We analyzed the participant' use of the proposed system by checking the logs of the drawing function and the text chats for each group and comparing these with the video recording.

(1) *Behavior of the students*

Figure 7 and 8 show the changes in the number of text chats and the use of the drawing function in Group 1 every 5 minutes. In Group 1, there was an inverse relationship between the number of text chats and the use of the drawing function: there was a decrease in text chats and a corresponding increase in the use of the drawing function.

For example, there was a rapid increase in the number of text chats between 50 and 55 minutes, as shown in Figure 8. From the recorded video, we found that at 43 minutes and 42 seconds, the teacher instructed each group over Ustream to begin their discussions; at 50 minutes and 07 seconds, Student A from Group 1 requested to start discussions with Student B, and they started their discussion. We believe this to be the reason behind the decreased use of text chats.

Figure 9 and 10 show the changes in the use of text chats and the drawing function in Group 2. Unlike the case with Group 1, in Group 2, both the drawing function and text chats were used at the same time, as seen from these figures; we believe that in this group, the students were drawing their ideas on the whiteboard while simultaneously engaging in a discussion via text chat. However, between 45 and 50 minutes, the use of text chats, which thus far had been used continuously, suddenly disappeared and was replaced by an increased use in the drawing function. We believe this was because at 43 minutes and 01 seconds, Student C from Group 2 proposed a concrete design to Student D, and in response, both the students started drawing on the whiteboard.

Although the students had the option of communicating within the group using Skype voice calls, none of the students used this medium; they exclusively used text chats and the whiteboard for communication.

(2) *Behavior of the teacher*

We analyzed how the teacher observed the learning activities of multiple groups. Figure 11 depicts a graph of the duration at which the teacher observed each group in detail or intervened in the activities of those groups.

In this experiment, the teacher began to use the proposed system after 9 minutes and 44 seconds. Therefore, we recorded the durations at which the teacher observed each group in detail after 10 minutes from the start of the experimental lesson. In the following 10 minutes, the teacher requested the students for the use of text chats in response to the teacher's lesson; the teacher also checked the students' text messages while switching between groups frequently.

Figure 11 shows that the highest duration of time that the teacher observed each group in detail was between 30 and 45 minutes. From the recorded video, we found that the teacher spent more time observing Group 2 from minutes 30–35 and spent more time observing Group 1 from the minutes 40–45. From the recorded video, we noticed that the teacher was checking to ensure the success of each group while simultaneously checking the text chat logs. We also believe that the teacher observed each group in detail for a longer duration, because the number of ideas being drawn on the whiteboard was increasing toward the end of the first half of the lesson.

From the recorded video, we could see that the teacher called for a break for less than 10 minutes, from 40 minutes and 45 seconds to 50 minutes and 08 seconds. Therefore, at the elapsed time of 45–50 minutes, the teacher observed each group in detail for less than 50 seconds. On the other hand, the students continued their learning activities even though the teacher was not virtually present.
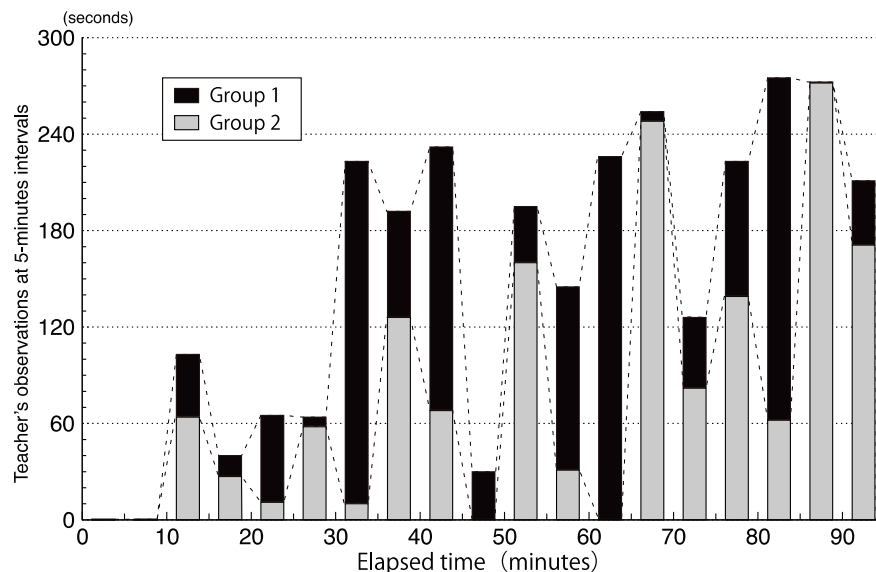

Figure 11. Durations at which the teacher observed each group in detail or intervened

147

At the elapsed time of 60–65 minutes, the teacher observed Group 1 in detail for longer than 200 seconds, but the duration that the teacher observed Group 2 was much shorter. This is because the teacher intervened in Group 1's activities by drawing directly on the whiteboard from 62 minutes and 16 seconds to 64 minutes and 48 seconds. On the other hand, at the elapsed time of 65–70 minutes, the teacher observed Group 1 in detail for a very short time. We found that the teacher intervened in Group 2's activities by drawing on the whiteboard from 68 minutes and 22 seconds to 69 minutes and 40 seconds.

From Figure 11, we can see that at the elapsed time of 70–75 minutes, the teacher observed each group in detail for a short amount of time. Since the teacher observed the students—using the overall observation function—from 70 minutes and 29 seconds until 72 minutes and 23 seconds, the teacher did not have much time to use detailed observation at this time. In contrast, after the elapsed time of 80 minutes, the teacher observed each group in detail for a longer time. It is because the teacher commented on and displayed the outcomes of each group over Ustream.

Although the teacher could use Skype voice calls to communicate with either group, the teacher did not do so. If the teacher needed to communicate with both groups simultaneously, Ustream was used; when the teacher had to communicate with specific members of either group, text chats were used.

5.2.2 Evaluation by the participants

(1)   *Evaluation by the students*

Table 2 shows the results of the questionnaire survey conducted for the students. The first three questions pertained to whether the proposed system could support students as a communication tool. The results showed that the students gave high ratings for both the shareable whiteboard and the text chat function. Based on opinions such as "it's useful" and "it's convenient," elicited from the free description section of the questionnaire, we can say that the proposed system was considered a useful communication tool for collaborative learning.

The next four questions pertained to whether the students were able to focus on collaborative learning with the constant presence of other students and the teacher. The results revealed a few affirmative answers, such as "agree," and some neutral answers, such as "undecided." For example, 50% of the students responded that they were "undecided" about whether the constant presence of the teacher made them feel tense or relieved. Since the teacher mentioned that he/she could observe the students' learning activities and comment on them several times during the experimental lesson, we thought that the students would be conscious of being constantly observed by the teacher. However, the students did not feel as tense and relieved as we expected.

Table 2: Results of the questionnaire for students (N=4); the 5–1 scale corresponds to "agree," "moderately agree," "undecided," "moderately disagree," and "disagree."

Questions	Answers (number of persons)					Mean
	5	4	3	2	1	
You could express your opinion through the whiteboard	3	1				4.7
You could ascertain others' opinions through the whiteboard	2	2				4.5
It was helpful to exchange opinions using text chats	3	1				4.7
You were able to focus on collaborative learning with the presence of the teacher and other students	2	2				4.5
You were able to learn even though you felt tense and relieved because of the teacher's observations		2	2			3.5
You could recognize the quality of the activities because of the teacher's direct instructions		4				4.0
It is necessary to cease operations while the teacher is instructing you directly	1	1	2			3.8

When the students were asked whether it was fitting for them to stop drawing on the whiteboard while the teacher intervened, none of the students said they "disagreed"; however, their answers ranged between 3 and 5. We think this is because those students misunderstood the intervention as a system malfunction, and they did not notice that the teacher had actually intervened. From the recorded video, we noticed that while some students paid careful attention to the teacher's intervention, there were others who did not even notice that the teacher had intervened; they continued to operate the system (for example, turn pages). Based on this finding, we believe that, in the future, it will be necessary to investigate how a teacher can intervene and manage his/her students' operation of a system, and how a system can be configured such that a student gets a notification whenever a teacher intervenes.

In the free description section of the questionnaire, one of the students commented that the function for voice communication was not built into the proposed system. This student was unable to talk to the teacher via Skype when the teacher does not operate to connect with the Skype even if the student wanted to communicate with the teacher. Therefore, we thought that the students found it inconvenient to use the different means of communication, which could be why they did not use Skype voice calls.

(2)   *Evaluation by the teacher*

Table 3 shows the results of the questionnaire from the perspective of the teacher. We found that the proposed system received high scores, overall. However, the teacher gave a low score for the question on whether it was helpful that the students cease operation when the teacher intervened. Further, in the free description section of the questionnaire, the teacher provided the following feedback: "Students could not draw on the whiteboard during my intervention (I was worried about students' time constraints)." Since the students were not allowed to operate the system while the teacher intervened, we believe that the teacher hesitated to intervene and stop the students' activities, considering their time constraints.

Table 3: Results of the questionnaire for the teacher (N=1)

	Questions	Answers
Overall observation	The system helped you grasp the learning progress of multiple groups	4 (moderately agree)
	The text chat function, by which you could transmit messages to all groups simultaneously is necessary	4
Detailed observation and intervention	The system helped you grasp the learning progress of specific groups	4
	Joining the text chats of specific groups was helpful to grasp their learning progress	5 (agree)
	You could advise students on procedures related to their learning	4
	You could instruct students on issues related to the content	4
	The fact that students had to cease operations while you gave instructions was helpful	2 (moderately disagree)

6. Conclusions

In this study, we developed a shareable whiteboard system for use in collaborative learning, whereby a teacher could observe multiple groups simultaneously and provide instruction from a remote location over a network. The developed client server system consisted of a client system for students, a client system for teachers, and a server system for management. The client system for students was equipped with a shareable whiteboard. Moreover, the client system for teachers allowed the teacher to observe and provide instruction to multiple groups simultaneously.

In this study, we conducted an experiment using the proposed system and acquired usage log files and video recordings. Based on these records, we found that the students were successful in collaborative learning. In addition, we also found that the teacher could instruct students in three ways: through overall observation, detailed observation, and intervention, where required. Further, the

participants responded positively to the questionnaire. Therefore, we believe that the proposed system works favorably for collaborated learning.

In terms of drawbacks, we found that the proposed system did not have adequate functions such as voice chat, exchange of information among other groups, and controlling permission of drawing. If we were to overcome these drawbacks, we believe that the proposed system would be very valuable. Yet another drawback is the sample size. In this study, we conducted the experiment using only five participants. This number is not large enough to be representative of a larger sample. We should note that there are various forms of collaborative learning other than the type used in this study. Therefore, by way of further study, we would like to investigate the proposed system in different lesson with a larger number of participants.

Acknowledgement

References

Sugimoto, M., Kusunoki, F., Inagaki, S., Takatoki, K., Yoshikawa, A. (2002). A system for supporting collaborative learning with networked sensing boards. *The IEICE Transactions on Information and Systems, J85-D-I*(12), 1152-1163. (in Japanese)

Kaneko, D., Noboriguchi, Y. (2007). A development of peer review and group learning system and its application to basic ICT education. *Japan Journal of Educational Technology, 31*(Supple.), 33-36. (in Japanese)

Obata, A. (1998). Video and shared whiteboard effects on remote cooperative work. *Journal of Information Processing Society of Japan, 39*(10), 2752-2761. (in Japanese)

Kobayashi, K. (2002). Co-constriction of evaluation process internalized in classroom discourse. *Bulletin of the Education Faculty, Shizuoka University. Liberal Arts and Social Sciences Series, 52,* 279-292. (in Japanese)

Gall, U., Hauck, F.J. (1997). Promondia: A Java-based framework for real-time group communication in the Web. *Computer Networks and ISDN Systems, 29,* 917-926

Koga, A., Nishiyama, H., Tanaka, T., Hirose, M. (2002). Development of learning process authoring tool and learning environment for collaborative learning. *The FY 2001 Project Reports Rev.2,* IPA Japan. (in Japanese)

Matsuuchi, N., Nishiuchi Y., Shiba, H., Yamaguchi, T., Mendori, T. (2010). TERAKOYA learning system linking multipoint remote users for supplementary lessons. *Information and Systems in Education, 9*(1), 35-44.

Ito, K., Sakai, S., Akahori, K. (2003). Development and education of shared whiteboard for supporting collaborative learning. *Japan Journal of Educational Technology, 27*(Supple.), 77-80. (in Japanese)

Suzuki, S., Mizukoshi, K., Fukazawa, M., Yatsushiro, K., Torikai, E. (2013). A proposal of connection method and evaluation of a distance learning support system built on the network between schools. *IPSJ Journal, 54*(3), 1050-1060. (in Japanese)

Roseman, M., Greenberg, S. (1996). TeamRooms: Network places for collaboration. *Proc. of Computer supported cooperative work '96*, 325-333.