Group Scribbles to Support Knowledge Building in Jigsaw Method

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Abstract—The jigsaw method empowers students to build their own knowledge through successive engagement through interactions in original group discussions and in expert group discussions. However, when students return to their original group to share with teammates what they have learned in their expert groups, they may need to review the records of the previous discussion in order to integrate and share the key ideas arising from that discussion. Paper-and-pencil records often do not meet students’ needs for sharing and discussion, thereby affecting the efficacy and efficiency of the learning and knowledge-building (KB) processes. Group Scribbles (GS) is an activity tool that enables the collaborative generation, collection, and aggregation of ideas through a shared space. The aim of this study is to deploy GS with Tablet PCs to facilitate 12 graduate school students doing cooperative learning by the jigsaw method and to examine how GS supports KB processes.

Scribbles (GS) is an activity tool that enables the collaborative generation, collection, and aggregation of ideas through a shared space. The aim of this study is to deploy GS with Tablet PCs to facilitate 12 graduate school students doing cooperative learning by the jigsaw method and to examine how GS supports KB processes.

Index Terms—Cooperative learning, collaborative learning, jigsaw method, knowledge building.

1 INTRODUCTION

Traditionally, schools in Taiwan are dominated by the teacher-led, chalk-and-talk approach. In comparison with teacher-centric instructional approaches, cooperative learning is a learner-centric approach in which students split the learning task into subtasks, solve the subtasks individually, and then get together to assemble the partial results into the final output. The jigsaw method [1] is one of the cooperative learning strategies implemented in a graduate course, Open Source Learning Management System (OSLMS), conducted by one of the coauthors. The goal is to enable students to compare and contrast the strengths and weaknesses of different OSLMSs. In the course, each group is given a list of subtopics to research, and each member is assigned a section to study. Then, they meet in expert groups with their counterparts from other groups for discussion. Next, the students return to their original groups in the role of expert or instructor for their subtopic. However, in the previous year, there is one challenge that authors meet in the learning process. Some students are familiar with their assigned learning only. They tend to neglect other expert groups’ idea improvements and conclusions and pay much more attention to their own subtask learning and expert group discussion. As a result, students cannot understand the characteristics of other OSLMS very well and they may fail to contrast the strengths and weaknesses of different systems. The major reason is that, while returning to original groups to instruct and share knowledge obtained by their expert group discussion, some students need to frequently review the previous notes of his/her own to recollect key information. When the students are challenged during the interactive questioning, they may also need to review the notes of members within the same expert group to integrate key information back to their original group discussion. When they find the records to share notes of her/his own or others, other original group members may not see the notes clearly due to the limited size of A4 paper. The lack of a mutual interface for common sharing and discussion affects the student’s intention to seek to understand and incorporate the outcomes of expert group negotiation and improvement of ideas, and subsequently influence their opportunities for learning thinking, analytical, inquiry, and problem-solving skill. In addition, the free-rider effect [2] may exist during group discussion. These problems include members not participating, groups not getting along, or learners unable to do the task which can profoundly affect students’ knowledge building (KB), which in this paper refers to deep understanding through interactive questioning, dialogue, and continuous improvement of ideas.

To solve the issue, the study aims to implement an efficient interface for communication facilitating student’s sharing and interaction. The use of technology in the classroom has increasingly been the object of study in recent years, and one of the more rapidly advancing subfields is cooperative and collaborative learning supported by hand-held mobile devices. An appropriate solution is Group Scribbles (GS), developed by SRI international [3], [4], which enables collaborative generation, collection, and aggregation of ideas through a shared space based upon individual effort and social sharing of notes in graphical and textual form. Other studies [5], [6] have shown the efficacy of using GS in elementary science classrooms to foster rapid collaborative KB; in these studies, even primary school students and teachers find GS easy to learn and flexible to use for a range of activities and subjects.

Computer environments have proved to be very helpful in organizing applications of Jigsaw-based methods in learning situations. However, no research has so far been done on implementing the jigsaw method using a flexible collaborative tool like GS to support KB. Therefore, in this study, we use jigsaw assignments supported with Tablet PCs and GS to support students’ KB on the graduate course topic of OSLMSs. By presenting an analysis and a discussion of the roles of GS mediated in a jigsaw activity, this paper reports an exploratory study designed to investigate whether GS facilitates a participant’s KB in jigsaw cooperative learning. The research questions to be addressed in this paper are as follows:

- With GS, how do students interact with others during group discussion in a jigsaw activity?
- To what extent do GS benefit students in having rich interactive questioning, dialogue, and continuous improvement of ideas?

This article is structured as follows: The next section is a review of the literature, addressing both theoretical and empirical aspects of KB, the jigsaw cooperative learning model, and constructivism theory. The third section describes the research design. The results for the various analyses are presented in the latter sections. Finally, conclusions are presented and suggestions are made for further research.
2 LITERATURE REVIEW

2.1 Knowledge Building

According to constructivist principles, knowledge is not a static, inert object to be sent and received. Rather, knowledge is a fluid set of understandings shaped both by those who originate it and by those who use it. As Scardamalia and Bereiter noted, knowledge is socially constructed, and this process can be supported through collaborations designed so that students share knowledge and tackle projects that incorporate features of adult teamwork, real-world content, and use of varied information sources [7].

The definition of KB in this study can be considered as deep constructivism [7] which involves developing deep understanding through interactive questioning, dialogue, and continuous improvement of ideas. KB among groups not only provides opportunities for mutual learning and cooperation which stimulate the creation of new knowledge, and help develop better thinking, analytical, inquiry, and problem-solving skills, but paves the way for students to develop their life-long learning abilities and attitudes as well [8]. KB advances the current understanding of individuals as a group and within a group, at a level beyond their initial level of knowledge, and is directed toward advancing the understanding of what is known about that topic or idea [9].

2.2 Cooperative Learning Method: Jigsaw

In comparison with the lecturing methodology and its teacher-centric instructional approach, cooperative learning emphasizes learner-centric approaches that empower students to build their own knowledge system by interactively communicating and discussing in groups. Cooperative learning is an instructional paradigm in which teams of students work on structured tasks (e.g., homework assignments, laboratory experiments, or design projects). They do it under conditions that meet five criteria: positive interdependence, individual accountability, face-to-face interaction, appropriate use of collaborative skills, and regular self-assessment of team functioning [9]. As frequently pointed out by Johnson and Johnson, classroom learning improves significantly when students participate socially, interacting in face-to-face collaborative learning activities with small groups of members [10]. Previous studies [11], [12], [13], [14], [15], [16], [17] have also shown that, when correctly implemented, cooperative learning improves information acquisition and retention, higher-level thinking skills, interpersonal and communication skills, and self-confidence. Classroom settings that invite collaboration are likely to engage students. Both effort and attention remain at high levels.

In jigsaw, each student in a group of four to six members is given a specific piece of a problem based on a particular viewpoint that the whole group is studying. After the students have studied and become experts in that piece of the problem, they meet in expert groups with their counterparts from other groups to focus on the problem. Next, the students return to their original groups and share with their teammates what they have learned previously.

Two crucial concepts of jigsaw relate to the amount of group support and to the degree to which each individual member of the group needs to learn and to exhibit his or her accomplishments. The first is positive interdependence, the perception among group members that what helps one group member helps all group members and what hurts one group member hurts all [18]. The second crucial element is individual accountability. Slavin defines individual accountability as being present when the team’s success depends on the individual learning of all team members [19]. To accomplish this, the groups encourage all members to participate and to meaningfully demonstrate their knowledge and skills.

2.3 Constructivism Theory

The pioneer of constructivism, Jean Piaget, articulated mechanisms by which knowledge is internalized by learners. He suggested that, through processes of accommodation and assimilation, individuals construct new knowledge from their experiences. When individuals assimilate, they incorporate the new experience into an already existing framework without changing that framework. By contrast, accommodation is the process of reframing one’s mental representation of the external world to fit new experiences [20]. The contemporary constructivist theory of learning acknowledges that individuals are active agents, and they engage in their own knowledge construction by integrating new information into their schema and by associating and representing it in a meaningful way. Constructivists argue that it is impractical for teachers to make all teaching decisions and to dump the information on students without involving students in the decision process and assessing students’ abilities to construct knowledge. In other words, guided instruction is suggested, which puts students at the center of the learning process. Piaget [20] also highlighted the convergence of the social and practical elements in learning by saying that the most significant moment in the course of intellectual development occurs when speech and practical activity, two previously completely independent lines of development, converge.

2.4 Mobile Learning

Mobile, handheld devices are growing in importance in education, in part because they are much more affordable than conventional laptop or desktop computers [21]. Continued innovation has brought Web-enhanced technology to mobile devices (e.g., Tablet PC, PDA). According to [4], innovators need a common, reusable, and easy-to-maintain framework for implementing patterns of collaborative learning on wireless handheld devices. The instant, communicative, and interactive characteristics of the devices could perfectly adapt to collaborative learning. In the study, hand-drawn sketches, enabled by the inking affordances of Tablet PCs, can be more expressive of the key concepts one wishes to communicate than a neat, chiseled presentation would have been [4]. An informal sketch may be able to solicit participation of others in active reasoning more effectively than a more formal, fixed diagram would have. Moreover, the act of drawing, gesturing, and speaking in close synchrony allows one to focus the attention of others on the meaning of the diagram he was preparing [22]. Effectively supporting students’ face-to-face interactions, and elaborating on students’ interaction as well as coordination in cooperative learning, becomes possible with the use of the mobile device.

Technologies that leverage mobile devices to transform classroom practices around collected and aggregated student work include student response systems, often called clickers, and classroom presenters [4]. In a student response system, an instructor asks students a probing multiple choice question. Every student responds with his or her answer on the clicker device, and the results are aggregated into a histogram that provides instantaneous formative feedback for the instructor to adapt her instruction. Tablet PCs allow richer interactions than those possible with a clicker. One such application on Tablet PCs, the Classroom Presenter, takes as its starting point a prototypical classroom situation in which an instructor presents prepared PowerPoint slides. The instructor can gather students’ annotations or sketches on a particular slide and use this collected information to drive further classroom discussion. While clickers and the Classroom Presenter are powerful classroom innovations, they
both presume that the teacher coordinates all classroom interactions explicitly [4]. They do not support coordinated use of the technology among students. Thus, we choose GS, a software platform that supports generalized coordination among students and the instructor and, in particular, to support the jigsaw method which requires sharing and coordination when students rotate among expert and original groups.

3 RESEARCH DESIGN

In this section, we describe how we design the study and the course activities. We will highlight the data we collect in the study. We will also briefly explain how GS works.

3.1 Students and Group Composition

The instructor, who is fluent with GS, designs the empirical study which involved students from the “Web-based LMS” course in the Graduate Institute of e-Learning Technology, National Hsinchu University, Taiwan. The learning goals are to familiarize with the OSLMS and to evaluate the three OSLMS through peer tutoring, group sharing, discussion, and negotiation. Out of the 12 students, half are female. Their ages range from 22 to 37 years. Participants are grouped one month before the jigsaw experiment. Three of them report prior experiences with using GS and have some concept of the learning task due to their prior learning experiences. They serve as the experienced participants assigned to be leaders in three original groups (g1, g2, and g3) to initiate and facilitate group discussions. The rest of the nine students are allocated to three original groups on a random basis, with each group having four members.

Each group member is required to research one OSLMS (Atutor, Moodle, or Sakai) and has to set up the assigned platform and to be acquainted with its operation and the functions of the administrator client, the teacher client, and the student client. In the jigsaw experiment, they meet in expert groups with their counterparts to discuss both the strengths and weaknesses of the assigned OSLMS. Meanwhile, the three original group leaders are also assigned as expert group leaders to initiate and facilitate group discussion. Later, the students return to the original groups for sharing their expert group discussion outcomes with their teammates. Their overall goal is to compare the three OSLMS in several aspects. Fig. 1 shows the group compositions. The students are told prior to their participation that we were interested in exploring how GS can support group interaction and KB in the jigsaw method; they are not told, however, what types of results are expected.

3.2 How Group Scribbles Works

GS is based on a simple but flexible, powerful, and extensible software engine called Tuple Spaces from IBM that allows for coordination among many concurrent processors in a network. It is designed to support the coordination of different processors and operates on a variety of client computing devices, including laptops, Tablet PCs, and PDAs [23]. The GS interface presents each student with a three-paned window, as shown in the student’s interface in Fig. 2.

The lower pane is the user’s personal work area, or “private board,” with a virtual pad of fresh “scribble notes” on which the student can draw or type. The “tool bar,” shown to the right of the private board, allows users to select the color of note and choose either drawing or typing on scribble notes. A scribble can be visible to others by dragging it into the “public board” (or their own “group board”) in the upper pane, which is synchronized across all devices. The reverse drag makes the item private again. Users may interact with public scribbles in a variety of ways, such as browsing their content, repositioning them, or moving one from the public board into their private space. New public boards can be created to support multiple activities or spaces for small groups to work.

The teacher’s interface has the additional administrator board added in the left window frame, as illustrated in Fig. 3. This frame shows the list of the students and the grouping of the students. In the student listing, a green dot means that the student is online, while a red dot means that that student is offline or absent. On the top of the pane, the function of the group composition is provided which helps the teacher to change the composition of the group by simply dragging names from the student list.

As shown in Fig. 4, the scribble note is roughly the size of $3 \times 3$ inches, and has properties similar to 3M’s familiar Post-It note. The user can draw or type on the scribble note and drag it into upper pane or different screen arrangements. The user can select a unique background color for his or her notes for identification purposes. In addition, the student’s ID and name are included in the note to provide awareness of the authorship. The user can right-click the mouse on the note to select further functions, for example, to use the clone function to make a copy of the note.
3.3 Educlasses LMS

Educlasses [24], a Learning Management System (LMS), is integrated with GS to enable the instructor to add curriculum and learning activities for the students to select from a portfolio of developmental activities.

3.4 Tablet PCs

We use Tablet PCs in the research, as we had found that a moderate screen size and the mobility of handheld devices during interaction and discussion provide flexibility for the students in doing the jigsaw activity. All 13 Tablet PCs (including one for the teacher client) had a 12.1-inch display with 1,024 × 768 resolution.

3.5 Design of Activity

The aim of this research design is to deploy GS with Tablet PCs to facilitate 12 graduate school students doing cooperative learning by the jigsaw method and to examine how GS facilitates student's KB. The theme of the graduate course, OSLMS, typically offers a wide variety of tools and approaches to make a Web-based course more effective: creating and delivering materials, video conferencing, discussion forum and chats, giving quizzes and surveys, gathering and reviewing assignments, and recording student performance and grades. By being open source, anyone can download, use, and modify the software. The learning task for the students is to explore and contrast three OSLMS: Atutor, Moodle, and Sakai in several aspects. Atutor is cited as unique for its accessibility features and for its suitability for educational use. Moodle, an acronym for Modular Object-Oriented Dynamic Learning Environment, has a significant user base with over 47,515 registered sites with 21.9 million users in 2.1 million courses (as of July 2008). Sakai, a Java-based and service-oriented application suite, is designed to be scalable, reliable, interoperable, and extensible.

The instructor sets up GS software in each Tablet PC and ensures that each device is connected to the Tuple Spaces server in order to run GS. The background blank tables for expert and original groups are uploaded to GS beforehand. During the students’ interaction and communication, the instructor provides guidance and assistance on the course topic OSLMS, or trouble shooting of GS. The whole activity is videotaped for analysis. Here is a description of the sequence of activities:

1. **Log in and configure group (20 minutes).** After the students have enrolled and logged into GS, the instructor uses the function of teacher administrator of GS to configure students into three expert groups so that four expert group members with Tablet PCs could sit together to facilitate communicating and discussing.

2. **Operation of GS (10 minutes).** Students practice how to write/type on, drag, and drop the notes from a private board to the public board of GS using the digital stylus of the Tablet PC.

3. **Expert group discussion (30 minutes).** In each expert group, the students are asked to discuss the strengths and weaknesses of their assigned OSLMS using an organizer with items as “system setup,” “administrator function,” “teacher function,” “student function,” “interface,” and “other.” Students have to produce, share, and advance the knowledge of the collective. Students discuss and write/type their ideas on the scribble notes and drag/drop them on a blank table (uploaded by teacher beforehand) on its expert public board, as shown in Fig. 5. The instructor monitors the students’ interaction and saves the results as files using the function of the teacher administrator.

4. **Original group discussion (40 minutes).** Each student returns to the original group with his or her Tablet PC to share the results of his or her group’s discussion. After the members have acquired some basic understanding of all three OSLMS in their original group, they begin to discuss and contrast the strengths and weaknesses of three platforms item by item, as shown in Fig. 5. Each student could switch back to the expert group table by clicking icon at the right
of the upper pane (shown in Fig. 6) to refer to or review what they have originally constructed during the expert group discussion. They can create new scribble notes or copy/edit any scribble notes from their expert group result and paste it onto the OSLMS comparison table. Next, each group has to integrate various contributed information and achieve new synthesis. They also grade different OSLMS functions on the comparison table with \( C_1 \rightarrow C_2 \rightarrow C_3 \), which represents excellent, good, and no good, respectively. The comparison tables of three groups are also saved as files immediately after the activity. Fig. 6 shows an example of the OSLMS comparison table (g3).

5. Group presentation (20 minutes). One student in each original group uses a single-gun projector to display and report results to the whole class. The instructor initiates class discussion and encourages the students to compare and contrast the ideas with those of others.

6. Questionnaire (20 minutes). The students respond to 10 items on a Likert scale of 1 to 5, indicating the degree to which they agree or disagree with statements concerning their opinions about GS interface operation, interaction, and KB mediated with GS.

7. Interview (30 minutes). Following the activity, the students are interviewed for approximately half an hour about KB and interaction experience with GS. The interviewing data is intended to serve as an additional source of information to supplement the questionnaire survey.

3.6 Data Collected

Our source of data includes the contents of the posted scribble notes and of the group boards in GS, the returns of questionnaire survey, the after-class interviews, a videotape of whole activity, and the instructor’s observations.

4 RESULTS AND DISCUSSIONS

We report a quantitative analysis of the scribble notes created during the different stages in the jigsaw interaction, as well as the results of the questionnaire. We also discuss the analysis of the videotape and other observations in this section.

4.1 Generation of Scribble Notes

4.1.1 Expert Group Discussions

Table 1 shows the number of scribble notes created in the discussions in the expert groups with their means and standard deviations. The Min and Max show the minimum and maximum notes generated by a member, while the total reflects the total number of notes generated. Among the three expert groups, Sakai members contribute 33 notes, the greatest number of notes for a group (\( M = 8.25 \)), whereas Atutor members contribute relatively less (\( M = 6.75 \)). Since the software operation and wireless access is not very stable, two students, student 4 (Atutor group) and student 5 (Sakai group), could not contribute their ideas very smoothly. Student 10 in the Sakai expert group is a very active student and he contributes 16 ideas.

4.1.2 Original Group Discussions

When the students return to the original group to interact and contrast several functions of three OSLMS, they use the same function of GS to drop their ideas onto the comparison table. The statistics of the scribble notes generated in the original groups are shown in Table 2. The columns from Atutor, Moodle, and Sakai denote the number of notes created by the member from the Atutor, Moodle, and the Sakai group, respectively. Among the three original groups’ discussion, g3 members contribute the highest 35 integrated notes (\( M = 8.75 \)). g1 students have relatively low means (\( M = 6.00 \)) because they spend a lot of time on discussion and negotiation in order to derive their conclusions. On the contrary, g3 members have comparatively less dialogue during the interaction, mainly because they focus on creating new ideas.

4.1.3 Knowledge Building

Since students may switch interface between the group boards of expert and original groups by clicking the icon at the right of the upper pane, they can copy and edit any scribble notes from their expert group table and paste it onto the comparison table in the public space of the original group. In the comparison table (Fig. 6), the scribble note (marked by the circle shape) which says “easy and flexible to use” was copied intact from the expert group table (Fig. 5). Some scribble notes are identified as notes which are edited from those in the expert group tables which have similar meaning and expression. For example, in the expert group table (Fig. 5), the scribble notes (marked by the oval shapes) which say “powerful function” and “a lot of functions” were integrated into one note which says “multiple and powerful functions” in the
comparison table (Fig. 6). There are also some notes specified as new which do not appear in the expert group tables. The numbers of copied, revised, and new scribble notes in original group tables are shown in Table 3. The percentages of copied and edited scribble notes are 46 percent (g1), 90 percent (g2), and 80 percent (g3). Analysis of the videotape also shows that students use the function of GS to switch the interface between original and expert group tables frequently. In this case, g2 and g3 students tend to borrow ideas from previous records. However, g1 students report that their new ideas are derived out of inspiration, which helps the generation of more ideas. The possible explanation is that GS not only enables students to shift interface and view the discussion notes between the boards of the original and expert group effortlessly, but provides participant’s opportunities for mutual learning and cooperation that stimulate the creation of new knowledge and help develop better thinking and analytical skill. Participants take advantage of the GS function of interface shift for public discussions and interaction, and thereby enhance their KB with idea improvement and negotiation.

### 4.2 Analysis of Questionnaire

The questionnaire, composed of 10 items rated on a five-point Likert scale, ranging from “strongly agree” (5) to “strongly disagree” (1), is administered to the students after the course. These items are clustered around three factors: GS operation, students’ interaction, and KB. The means and standard deviations are computed on the students’ responses to the items and are presented in Table 4.

#### 4.2.1 GS Operation

The means of the first two items related to GS operation are 4.25 and 4.67 (SD = 0.49 and 0.42). More than 91.7 percent of the students agree or strongly agree that GS interface and operation is simple and easy to learn. Item 3, “I think the system lagging time is acceptable for me,” scores 2.33, which indicates that the software operation is not stable. As the system is still in the development phase, the students and instructor encounter some “frozen-screen” situations. From tracking the system usage logs, we find that the bottleneck could be possibly caused by the limitations of the Tuple Spaces server, insufficient wireless network capacity, and server overloading. This suggests that the current GS system is not sophisticated enough to support jigsaw cooperative learning without support from an experienced teacher fluent with GS or even a technology specialist. This finding urges us to improve the capacity of communication facilities and server loading to prevent communication jam problems from impeding the learning activities.

#### 4.2.2 Students’ Interaction

Items 4-6 are clustered around students’ interactions. Item 4 “Compared to paper-and-pencil experience, GS encourages me to express more ideas” scores 3.50, which appears to mean that students are not inspired to express ideas by using GS. For students, there is not much difference between GS and paper-and-pencil experience. Item 5 “On expert group discussion, GS enables me to quickly understand other’s views” shows that 11 students (41.7 percent + 50 percent) strongly agree or agree that GS benefited them for assimilating other’s ideas. In addition, item 6 “Compared with paper-and-pencil experience, GS improves the interaction among members” scores 3.92 and 75 percent students agreed with the statement. A partial explanation for this might lie in the fact that the lagging problem and frozen-screen situation interrupt students’ interactions.

#### 4.2.3 Knowledge Building

We seek to better understand whether GS supported students’ knowledge transfer by designing items 7-10. These questions score 4.17-4.42 and participants tend to agree or strongly agree with the statement that the records of previous discussion are crucial and GS benefited them for reviewing such records quickly so that they may integrate the knowledge to share with the original group members. The results might support the hypothesis that GS helps students to retrieve the previous discussion in the expert group to better understand the characteristics of OSLMS. Understanding of different systems can benefit students for comparing and contrasting the strengths and weaknesses among OSLMS after mutual learning and discussion.

### 4.3 Interview Data

The interview data is intended to serve as an additional source of information to supplement the questionnaire survey. The information is used to triangulate the students’ responses to the questionnaires. When asked to comment on the activity in the poststudy interviews, the responses toward GS for supporting KB in jigsaw cooperative activity are generally positive. Interview data brings out several interesting points regarding interaction and KB.
The findings reflect a positive attitude toward the jigsaw activity mediated with GS, as shown in the following student comments:

- **S3**: “For group discussion, I am used to typing important ideas or concepts with my notebook computer for records. Reviewing learning records is crucial for me in terms of learning. Sometimes I would pay too much attention to typing down every crucial idea instead of interacting with classmates. With GS in the jigsaw activity, I do not need to focus on typing due to the embedded saving functions of GS. In this case, I may devote attention to discussion and interaction and no ideas will be missed. GS benefits me to engage in group interaction to have better understanding of learning task.”

- **S5**: “I am not a quick learner. When I return to the original group to compare the strengths and weaknesses of three OSLMS, I usually shift to previous records to review the notes of characteristics of Atutor (assigned OSLMS). Those notes help me to recollect some important ideas quickly so that I can share with or even instruct original group members.”

- **S8**: “During discussion, two of original group members, Alibuda and Lij, had very different points of view toward the administrator function of Sakai and Moodle. Both members shift to previous records often and show the previous records to every member, trying to persuade everyone of us. When one note entitled ‘Chian’ is challenged and Alibuda failed to defend himself immediately, he moved over to other group to ask Chian, Alibuda’s previous expert group member, for better understanding. The similar process goes on and forth in different items. Obviously, the conclusion is not really satisfied to every member; however, after the intensive interaction with use of previous record, we better understand the similarities and differences between the two OSLMS afterwards.”

- **S10**: “A feature of GS is that there is an indication of the name of each member associated with the contributions. In addition, we were asked to choose a specific color in the beginning of class for distinction. In this case, it is easy for us to distinguish which sticky note is created by whom during discussion. Furthermore, with the indication of name and color coding, I got the pressure to pay more attention to express my ideas on shared space, especially when my contributions, sticky notes, are relatively less. However, I still have to post notes prudently because my name is just above my notes.”

The students also mention several interesting points regarding other aspects of GS:

- The writing function of Tablet PCs is similar to paper-and-pencil. (S2, S6, S11)
- GS will be a rather useful tool for cooperative and brain storming activities if the system lag problem is solved. (S1-S7, S9-S12)
- I think the lagging time is a critical issue which needs to be solved. For learners, they will never tolerate lagging problems during interaction. (S4, S8)
- Since all notes with names are on the shared space and it is easy to tell who contributes the least ideas, I will try to create or invent ideas to avoid being left behind. (S3, S5, S8)
- It is effective that GS can save the discussion records as files immediately. (S2-S8, S10-S12)
- With GS, it is helpful to be able to review the records of previous discussions to recollect ideas and knowledge integration. (S1, S3-S6, S8-S12)

The responses above were in accord with the positive responses from questionnaires. Two out of 12 students report that the discussions were interrupted due to the lagging issue which need to be resolved in a future study. Nine students hold the view that the GS is superior to traditional paper-and-pencil because they can either write or draw directly on screen and most of all, the discussion results can be saved as JPEG or BMP files immediately without additional word processing work. In addition, 10 students indicate that using GS on the jigsaw cooperative activity had a positive effect on their level of interaction and KB, for they could review the previous record to recollect important ideas. They deem that, in the jigsaw activity, the function of GS that helps them to assimilate group members’ ideas is valuable.

5 Conclusion

Our work provides an existential example of how a collaborative tool like GS can support the sharing and coordination processes of a cooperative learning method like jigsaw. The results of preliminary qualitative and quantitative analyses support our notion that GS supports group interaction in the jigsaw method. Our exploratory study shows how the affordances of GS are exploited to support the jigsaw activity, in particular, the sharing of information between the expert group discussion and the original group discussion to facilitate KB. As in traditional cooperative activities, there is a tendency for group discussion to be dominated by the more outspoken students. Nonetheless, with GS, introverted students do express their ideas by posting their ideas on the shared workspaces.

In the expert groups, participants create ideas on the group board, which the individual members refer back to when they discuss in their original groups. They refer back by copying the note or by editing a copy of the note, building up knowledge in the original group discussion by leveraging artifacts they created in the expert group discussion. Ten out of 12 students deemed it efficient to switch back to their expert group boards to retrieve previous notes as memory aids, especially when they were facing questions and trying to persuade other member of their viewpoints. They read the notes in recollecting the ideas or discussed with the note creator to seek a more comprehensive understanding. GS helps students to think and reflect on their thought processes, which provokes question asking and answering during interaction. This suggests that GS can facilitate rich interactive questioning for continuous improvement of ideas in the activity.

It is easy to recognize the authorship of the scribble notes by looking at the name and color coding on the note. The authorship awareness of notes in a shared space helps the instructor to better understand and evaluate individual contributions to the learning task. It helps students to distinguish authorship, which enriches their dialogues. This contrasts with the studies of GS used in elementary classrooms in which the scribble notes are anonymous [5], [6].

Three students of g3 reveal that, when they perceive that they do not have many individual notes in the shared space, they feel compelled to create more notes. While the intention to create more notes and thereby generate more ideas is good, they tend to spend much time composing their individual notes in their private boards, thus minimizing the time for interaction with the constraint of limited time allocated for the group discussion. This is a critical issue because it may affect the KB process: making a collective inquiry into a specific topic and coming to a deeper understanding through interactive questioning, dialogue, and continuous improvement of ideas. To solve the problem, the teacher should advise the students to devote sufficient time for...
social interaction to discuss and improve ideas in the notes besides devoting too much time to creating individual notes.

GS with the function of saving group boards enhances idea improvement: A major challenge in face-to-face learning is that, even though free-wheeling classroom discussion usually generates a lot of good ideas and questions, these ideas and questions are often abandoned for reasons such as time constraints [25]. With the save function of GS, the group’s discussion artifacts can be reviewed for continuous idea improvement.

The results of this exploratory study suggest that the GS-mediated cooperative learning jigsaw model can benefit students in their interaction and KB processes. These studies need to be treated circumspectly, as the results may reflect in part on the way in which the data were collected. Nevertheless, the research still makes contributions to the research and practice of using GS or other activity tools for supporting different cooperative and collaborative learning tasks. GS enables a shift from contiguous learning groups to distributed learning groups utilizing computer-supported collaborative learning environments. To improve the validity of the study, we suggested that future research should improve the design of learning activities with a bigger sample size. The current scribble note can be used to write only words or short sentences. We might need functions like file sharing to provide further evidences or information that might improve the software for KB. In addition, we need to plan longer learning cycles, extend the time of the jigsaw cooperative activity and to probe more deeply into the KB and phenomena that arises from the cooperation.

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