Active Participation and Collaborative Learning Leveraged by Interactive Digital Sticky Notes Technology

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Abstract: This study examines 10 weeks of collaborative learning activities that are supported by the GroupScribbles (GS) software technology in 2 Singapore Primary 4 Science classrooms. It is found that GS supports instant formative feedback from students and from teachers effectively. GS plays a positive role at both the level of individual learners and that of group learners. Several *emergent* collaboration behaviors manifested by students in GS were observed. With GS, the construction of knowledge is distributed across individual learners when they engage in social discourse within the activities. Students were found to have more opportunities to participate in class discussions to share and were better able to organize their ideas by using GS. The results show that the GS classes performed better than non-GS classes as measured by traditional assessments.

Keywords: collaborative learning, active learning, distributed cognition

1. Introduction

One of the key skills of workforce of the 21st century is collaborative learning: people work together to accomplish a common goal by maximizing their own and each others' learning, under conditions that involve both positive interdependence and accountability. To prepare the next generation for 21st century workskills, many countries have been advocating collaborative learning among K-12 students. In collaborative classrooms, groups of learners and their teachers routinely work in more complex configurations than lecture-based classes. They take roles, contribute ideas, critique each other's work, and together solve aspects of larger problems, all to good effect [1, 2]. However, the interactive technological supports for effective collaborative learning in classrooms have been far behind the expanding need.

One tool that can be used in classroom for collaborative learning is sticky paper notes which is good for brainstorming, prioritizing or visualization activities [3]. However, sticky paper notes have physical limitations such as the need for a lot of manual busy work (handing out, collecting, copying and duplicating, moving from place to place, etc.) as well as ongoing supply, archiving, and publication issues. It is also difficult for everyone in a large group to view a sticky note immediately, simultaneously, and remotely when someone publishes it. Another tool that has been used many classrooms for collaborative learning is Student Response System (SRS, sometimes called "clickers"), which has been found have powerful benefits in classrooms - for example, by enabling student groups to focus on improving their conceptual understanding [4]. However, this technology is limited typically to a very narrow range of representational types and information-sharing topologies. It supports only the most rudimentary of whole-group processes: the classroom analog of voting. Obviously, a lot of important conceptual work cannot be represented as voting. More powerful classroom network technology that can expand to richer representations and interaction topologies is needed.

GroupScribbles (GS) is an interactive technology which enhances the characteristics of sticky paper notes and SRS by providing their key features while avoiding some of their constraints [5]. Developed by SRI International, GS enables collaborative generation, collection and aggregation of ideas through a shared space. GS1.0 user interface presents each user with a two-paned window (Figure 1). The lower pane is the user's personal work area, or "private board", with a virtual pad of fresh "scribble sheets" on which the user can draw or type. A scribble can be shared by being dragged and dropped on the public board in the upper pane which is synchronized across all devices. The essential feature of the GS client is the combination of the private board where students can work individually and group boards or public boards where students can post the work and position it relative to others', view others' work, and take items back to the private board for further elaboration [6].

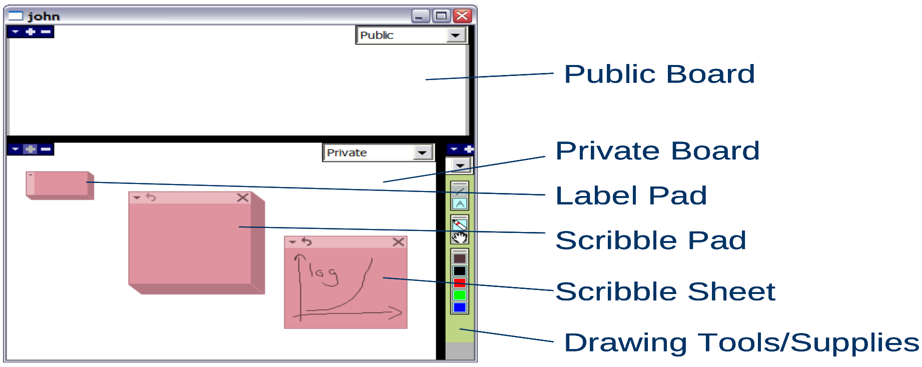

Figure 1: GS1.0 User Interface

GS has attracted significant attentions and interests in initial demos and uses by teachers, since its development and release in mid-2006 [7]. However, the application examples raised in the demos are still limited. So far GS had only been used in several illustrative, non-systematic learning situations. There is hardly any formal research evaluating its effectiveness, although it has received positive response from users [8]. With data collected from 2 Singapore Science classrooms in one semester, this paper examines whether GS-based activities can encourage students active participation, facilitate the collaborative learning and improve students' learning.

2. GS Intervention

In our work with a primary (elementary) school in Singapore, students and teachers from two primary 4 classes (one high ability class 4F and one mixed ability class 4C, each class has 40 students) were provided GS software user training for 2 sessions of an hour each. Subsequently, the classes switched to the use of GS technology for 10 weeks. Each week they had a one-hour GS Science lesson in the computer laboratory. Each student was fitted with a Tablet-PC (TPC) with GS client software installed. The GS was implemented in systematic learning situations where students used it to learn Science topics in Primary 4 curriculum syllabus - circulatory system, energy, light, and heat. The GS activities were co-designed by the researchers and the teachers. The GS activities were integrated tightly with the science curriculum topics. Here we present 2 activities as examples.

In a GS activity on light topic in week 7, the teacher showed a set of objects on the public board. Students in each group were asked to draw all possible shadows of these objects. The students viewed others' boards and made comments. Then they understood that objects cast different shadows depending on where the source of light is coming from (Figure 2).

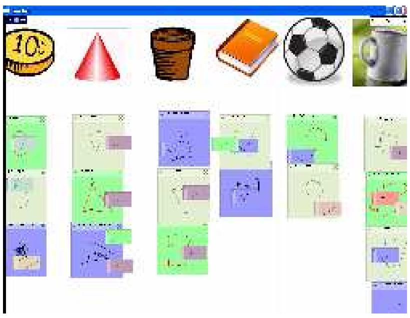

Figure 2. GS Screenshot of activity to predict shadows

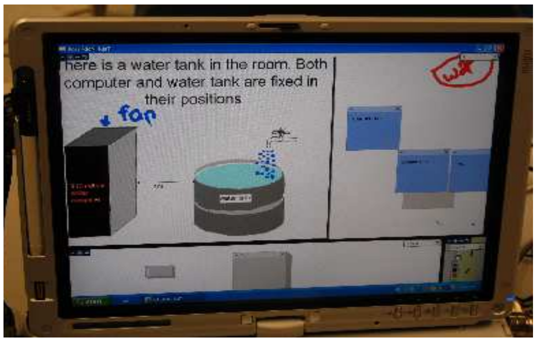

Figure 3. GS Screen of heat transfer activity

In another GS activity on heat in week 10, the students worked in groups of four to select suitable materials to make use of a water tanker to cool a computer. Group members 1 to 3 would each visit their respective resource rooms (group boards 1 to 3) to retrieve materials for the cooling system, and then discuss as a group how they would use the materials to design the system (Figure 3). Group member 4 served as the group leader. After all groups finished their designs, they visited other groups' boards to give comments. Each group then came to the front of the class and presented their solutions.

3. Data Collection

Three video cameras were set in the classroom to record the class (one camera that record the overall classroom proceedings, and the other two are each focused on a target group of students). At least 2 researchers observed each class and took down detailed field observation notes. The video recordings were collected and transcribed. After each lesson, we held sessions with each teacher to gather their feedbacks on the lesson and to give ourselves (teachers and researchers) a chance to reflect on what had happened in the classroom. We also collected the Science examination results of the students before and after the GS activities.

After the whole intervention, we conducted in-depth interviews with the 2 teachers and 8 target groups of students from each of the two classes. Before and after the GS intervention, students filled in a questionnaire survey on their attitudes towards collaborative learning. In addition, in the post-activity survey, we asked students' attitudes towards GS activities.

4. Findings

4.1 GS Support Instant Formative Feedback

We observed instances of the GS activities supporting instant formative feedback from the students and from the teacher effectively. With the rapid formative feedback from the GS, the teacher can literally *see* students' misconceptions immediately and take corrective action. For example, in the first GS activity, when the students were asked to post "what does blood transport" to the public board, some students posted "blood" and "vessel".

Such students seemed to manifest "associative" instead of "logico-deductive" reasoning. The teacher immediately pointed out the wrong answers and corrected them. Teacher L told us,

> "I particularly enjoy the instant feedback I get from my students' mass participation. I have many pairs of eyes to help me evaluate students' understanding. It saves on time as students help to edit postings during their visit to each other's board. They learn to reflect when comments are made on their postings. They learn through collaboration as they improve on each other's postings. This is indeed "more hands make light work". Students who are less inclined academically could learn from the instant feedback without feeling embarrassed."

4.2 Whole Class Participation with GS

We hypothesized that GS provide opportunities of every student to fully express their ideas in class because of the chance given to every student to post and the anonymity of the postings in GS. This is supported by the classroom observation and teacher interview. In classroom, we observed high levels of attention and participation from the students in the GS activities [9]. It is apparent that some students do not speak up in traditional class because they are shy. In the GS activities, the whole class was engaged, which benefits all the students especially those passive learners and shy students. As shared by Teacher L,

> "passive learners are given the opportunity to contribute as every member could participate at their own pace. Students are given plenty of opportunities to ask questions and to clarify their stand by posting and commenting. … The non-threatening atmosphere encourages the shy and reserve students to participate more actively."

These findings are consistent with the post survey findings on students' attitudes toward participating GS activities. As shown in table 1, 80% of the students strongly agree or agree that they have more chances to participate in the class discussion with GS, they are able to share more ideas to the classmates by using GS, and they get more ideas when using GS in class discussion.

Table 1. Students' attitudes toward participating GS activities (N=77)

	Strongly agree		Agree		Disagree		Strongly disagree	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%
I have more chances to participate in the class discussion by using GS.	32	42.7	27	36.0	13	17.3	3	4.0
I get more ideas when I use GS in the discussion.	36	46.8	25	32.5	12	15.6	4	5.2
I am able to share more ideas to my classmates by using GS.	35	45.5	26	33.8	12	15.6	4	5.2

4.3 GS Facilitate Students' Collaborative Learning

Different collaborative patterns were implemented when students were doing group work using GS. For example, in session 9, students used GS to brainstorm the best order (given a set of 4 materials - a newspaper, a plastic bag, tissue paper, aluminum foil) in which to wrap the ice cubes to slow down the rate of ice melting, and later implement their design. In session 10, students collaboratively solve a problem – how to cool down the computers by the materials given.

When students were doing group work, a typical collaboration pattern is: 1) individual group members posted to group board, 2) students exchanged group boards and gave comments and suggestions, 3) voted for the best board, 4) the members of the group that produced the best board presented their work to class (Figure 4).

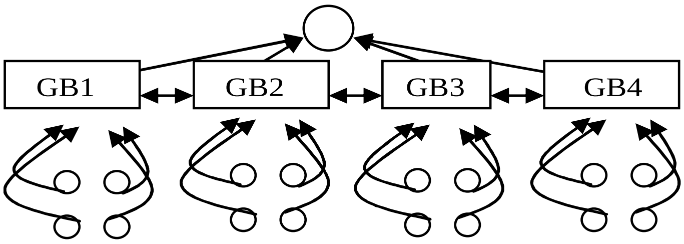

Figure 4. Typical GS-based collaboration pattern

Doing GS work together not only provides an opportunity to see and imitate what others are doing, but also to discuss the task and make thinking visible. Students may have different ideas and thoughts when they are mentally responding to a question or issue raised in class. When they communicate with each other (through verbal conversation or text communication via GS, and artifacts created in GS), they provide ideas, advice, and explanations, clear up misunderstandings, and finally negotiate and find a solution to solve the problem. As suggested by Scardamalia [10], when students are engaged in a group discussion, idea diversity helps them to understand an idea through understanding ideas that revolve around it, including ideas that are contradictory.

In addition, when doing GS work collaboratively, students learn from each other and help each other. As shared by Teacher L,

> "My weak students could learn from the postings of the higher ability students and the fast workers could guide the slow ones. With the introduction of GS, the learning experience enters a different phase. Students could discuss in groups without the need to drown each other's voice. "

Traditionally, students hold reservations about doing collaborative learning, possibly due to the individual nature of the traditional assessments and examinations. In pre and post survey, we asked students' attitudes towards collaborative learning to see if GS can improve their attitudes toward it. There were several questions which include or concern the collaborative dimension. The response scale is the following: 1=strong disagree, 2 =disagree, 3=agree, 4=strongly agree. The higher the score, the more likely the respondent agrees with the statement. Factor analysis with principle components extraction and Varimax rotation was conducted to identify important items for a meaningful interpretation of data, using a requirement all primary loadings greater than .60 and no secondary loadings greater than or equal to .30. The identified items that contribute the 2 different dimensions are:

1) Learning on their own – "I prefer working alone rather than in groups when doing science"; "I learn better when I discover things on my own"; "I learn more about Science working on my own", and
2) Learning with others in group – "It is effective when I work with other group members to solve a problem"; "I enjoy working in groups better than alone in class"; "I like the interaction among group members when we are doing group work".

Paired sample t test was employed to compare students' attitudes towards learning on their own, and collaborative learning before and after the GS interventions. The results in table 2 shows that after the GS intervention, on the one hand, students significantly less prefer to work on their own and less likely to believe they can work better on their own (t=3.609, p< .001). On the other hand, students are significantly more positive towards collaborating with others in group work (t=-2.023, p< .05).

Table 2. Paired-Sample t test in attitude towards collaborative learning (N=75)

		Mean	SD	*t*
Learning on their own	Pre Survey	2.51	.681	3.609***
	Post Survey	2.20	.682	
Learning with others in group	Pre Survey	3.28	.607	-2.023*
	Post Survey	3.43	.579	

Note: * $p < .05$, *** $p < .001$.

This result can be complemented with the descriptive results in post survey that measures students' attitudes towards GS in their collaborative learning (Table 3). It is shown that that more than ¾ of the students agree and strongly agree that their group works better to solve problems by using GS – their ideas are better organized and they themselves are more active in group work by using GS. This renders support to our findings that GS did play an active role in students' collaborative learning.

Table 3. Students' attribute towards GS in collaborative learning (N=77)

	Strongly agree		Agree		Disagree		Strongly disagree	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%
I am more active in group work by using GS.	29	37.7	28	36.4	16	20.8	4	5.2
Our ideas are better organized by using GS.	29	37.7	30	39.0	13	16.9	5	6.5
Our group works better to solve problems by using GS.	27	35.5	34	44.7	8	10.5	7	9.2

4.4 GS Classes have More Learning Gains in Traditional Assessment

We did a comparison on students' science examination scores at the end of the semester across all the 6 classes in the school, among which 2 classes (4F and 4C) were experimental classes with our intervention and the other 4 classes were control classes without our intervention (4A, 4B, 4D, and 4E). The science examination paper comprises 30 multiple choice questions, and 16 open-ended questions. The duration of the paper is 1 hour and 45 minutes.

Among the 6 classes, 4F and 4E were high ability classes whereas 4A, 4B, 4C, and 4D had students of mixed-abilities. As the students' abilities across the six classes were not the same, we considered their science scores of the previous semester as the covariate when comparing the science exam scores. We would normally expect higher-ability students to do better. Nevertheless, the results of Analysis of Covariance (ANCOVA) show that there was still a significant variation in science scores of the final semester among the 6 classes (F=3.342, $p < .01$) that cannot merely be explained by the previous semester's science scores (a proxy for the students' science abilities). Inter-class differences accounted only for 7% of the variance. The adjusted means of the current semester scores are shown in Table 4.

Table 4. Adjusted mean of the exam scores, controlling for the previous Science scores

	Class	Adjusted Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
GS classes	4F (High Ability)	65.973	1.376	63.261	68.684
	4C (Mixed Ability)	63.401	1.338	60.764	66.038
Non-GS classes	4E (High Ability)	61.180	1.290	58.638	63.723
	4A (Mixed Ability)	60.097	1.263	57.608	62.587
	4D (Mixed Ability)	60.010	1.311	57.427	62.593
	4B (Mixed Ability)	59.962	1.291	57.417	62.506

The overall ANCOVA test being significant, a cursory glance at Table 4 shows that our experimental classes (4F and 4C) float to the top in terms of adjusted mean scores. Detailed pair-wise comparisons were conducted as a follow-up to compare the exam scores between each pair of classes. The pair-comparison results show that GS "high-ability" class 4F had very significantly higher scores than the other 3 non-GS classes (F=9.12, 9.18, 9.86 respectively, p<.01), and higher (but not significantly) scores than 4C (F=1.57, p>.05) , the other GS class, which was of "mixed-ability". Class 4C had marginally significantly better adjusted-means compared to three non-GS classes 4A (F=3.40, p<.01), 4B (F=3.65, p<.01) and 4D (F=3.51, p<.01) and even did better (but not significantly so) against the "high-ability" class 4E (F=2.22, p>.05). There was no significant difference between any pair of non-GS classes. The ANCOVA results seem to suggest that GS had a significantly positive overall impact on the classes science examination results, whether they are of "high ability" or "mixed ability".

5. Discussion and Conclusion

This paper examines the effectiveness of GS in collaborative learning in two Primary 4 science classes for a semester of 10 weeks of lessons. The whole classes were engaged in the GS activities, from which the students benefited from being able to post their responses without the fear of discouraging or negative feedback from the class. In "traditional" classroom protocols, teachers usually do most of the talking and students are supposed to be listening. In a class of about 40 students, they could only ask one or a few students at a time to check their understanding. They would not be able to cater to every student even if they want to. GS not only opens up more channels of students' talking, but facilitates whole-class simultaneous communication at the children's level of understanding. GS supports instant formative feedback from students and from teachers effectively. With the rapid formative feedback, teachers can literally *see* students' misconceptions immediately and take corrective actions. Therefore, GS affords teachers more time to *care* about students' understanding (e.g. by polling through different group boards and by giving quick comments as students are working).

GS plays a positive role at both the level of individual learners and that of group learners. Learning is a process of cognitive reorganization of knowledge in the head which is a common notion that cognition resides "in the head" of the individual learner [11]. The view of distributed cognition recognizes that cognition occurs not only within the individual but cognition is distributed over the people, artifacts and activities [12]. With GS, the construction of knowledge is distributed across individual learners during which they engage in social discourse within the activities. Learners provide alternative views, organize information or view information from multiple perspectives. The individual learner's cognition is continually reorganized to construct meaning out of another person's view or perspective [11]. Cognition can be seen to be distributed across artifacts [13]. Using GS, every artifact created by every learner in his or her private space can be moved to the public space which can be viewed by everyone in the class. These artifacts can collectively represent the knowledge of the group, be re-arranged or organized to provide different perspectives, or archived and later used again to build upon new knowledge.

Several emergent collaboration behaviors manifested by students in GS were observed. The findings show that GS facilitates collaborative learning well. For the student, GS affords instant formative feedback from teacher and fellow students. When doing GS work collaboratively, students through interaction and feedback learn from each other and help each other to improve on the quality of ideas during the construction and re-construction of knowledge. As noted earlier, students are traditionally reluctant to do collaborative learning, due to the traditional assessments and examinations which mostly test individual work. GS intervention makes the students prefer "learning on their own" less and are more likely to work in groups collaboratively. With GS, students are more active in collaborative learning; their groups work better to solve problems, and to better organize their ideas.

The flexibility of the GS for collaborative learning activities encourages and inspires high-quality design of new activities and patterns. It provides a light-weight tool by which educators can create and enact collaborative learning activities in the classroom, both planned and in-situ. While our school-based work has generated many collaborative activities using GS for science learning, we believe that we have only started to probe the space of collaborative and coordinative work amongst students in the classroom. We expect that GS, building on the lessons from the learning sciences and with the right technological and pedagogical designs that are sensitive to on-the-ground realities, will make a positive impact on students' learning.

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