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A Study of GS-Based “Factor” Collaborative Learning in a Primary School

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Abstract: This paper reports the design of a GS-supported collaborative learning environment to empower fifth graders students’ conceptual learning in the primary mathematic classroom. The investigation of the effectiveness of the learning design through evaluating students’ learning gains. The result indicated that the proposed design could help enhancing students’ factor learning experiences. By analyzing the feedback questionnaires and interviews, finding that CSCL could promote the peers to interact positively, rely on and help with each other, and could elevate the pupils’ motivation and interests in learning. Suggestions were made at the end of this paper based on the results of this research providing for reference to further studies and practice teaching.

Key Words: CSCL, Factor, Group Scribbles

1. Introduction

In mathematics learning at the primary level, developing the concept of factor in students is an important goal. Conceptual learning often poses difficulty to primary school students as it requires substantial abstract thinking. As shown in previous studies, that students hold misconceptions of factor is common occurrence (Zazkis, 1999; Shih, 2007). To address this problem, educators and researchers are making efforts to identify effective instructional designs and teaching strategies that can enhance conceptual change.

From the constructivist perspective of learning, conceptual change is triggered by cognitive conflicts that arise when existing concepts are not sufficient to explain the perceived experience (Ferrari & Elik, 2003). Processing cognitive conflicts is an indispensable step to conceptual change (Posner & Gertzog, 1982; Posner, et al., 1982). Among all the instructional approaches proposed and practiced, collaborative learning has proved effective in encouraging cognitive conflicts and empowering the resolution of these conflicts through group discussions (Putnam, 1986, Dong & Guo, 1992, Robbins, 1996, Tedesco & Self, 2000). Apart from improving learning gains and the retention of the learning gains, student collaboration is also found beneficial to enhancing motivations, learning attitudes, self-efficacy, collaboration skills, and social skills in students. Students can also develop better problem solving, knowledge integration and application skills in these processes (Brown 2001; Johnson, Johnson, & Stanne, 2000; Slavin, 1995; 1999).

To better support and sustain student collaborations, Internet and Information Technologies (ICTs) are increasingly introduced to traditional classrooms. However, incorporating the technology alone is inadequate to improve student learning experiences. From past endeavors made in designing collaborative technology-enhanced learning environments, the importance of embedding suitable activity design to foster expected cognitive activities and social interactions is acknowledged (Lin , et al., 2014). To improve the conceptual leaning of factor in primary education, in our school-based research in Taiwan, we have designed a collaborative learning environment which is specifically tailored for conceptual learning integrating collaborative learning strategies and concept teaching strategies established in literature. This study investigates the effectiveness of this collaborative learning design by examining students’ learning gains, perceptions and behaviors.

2. Research Background and Goals

In this school-based research project, we integrated Group Scribbles (GS), a networked technology co-designed and developed by SRI International and Learning Sciences Laboratory to enhance student conceptual learning in primary mathematics classrooms. Based on a metaphor of whiteboard and sticky notes for collective construction of knowledge (Roschelle, et al., 2007), GS is conceived as a flexible platform for designing and enacting different forms of collaborative work via synchronous communication and interaction (Looi, et al., 2011; Chen, et al., 2012). In various classroom settings (including science and mathematics learning and language learning both at primary and secondary levels in Singapore), GS-supported collaborative learning has all proved effective in improving student learning gains, attitudes, and epistemology (Chen & Looi, 2011; Chen, Looi, & Tan, 2010; Lin , et al., 2014). Encouraged by these "successful" practices in authentic classrooms, we hoped GS could help transform traditional teacher-centered instruction to student-initiated exploration in Taiwan primary schools.

To bring collaborative learning into fruition, certain structuring or script should be embedded in the learning design to scaffold students' cognitive activities and social interactions. As factor learning has been the bottleneck for primary mathematics learning for long, various strategies for lesson design and enactment have been proposed and practiced to alleviate students' misconceptions (Zazkis & Campbell, 1996; Lin, 2002; Huang & Liu, 2002; Pape, 2004; Dias, 2005; Hsieh & Lin, 2006; Ke, 2007; Camli & Bintas, 2009). Reviewing existing literature, seven strategies, including: 1) reviewing and activating prior knowledge; 2) engaging contextualized and situated learning materials and experiences; 3) integrating hands-on experience, gaming, and multimodal representations; 4) providing timely explanations to and elaborations on word-problems (sometimes students have difficulty understanding word-problems due to deficient language proficiency); 5) providing diversified learning and practicing materials; 6) highlighting operation and verification in learning and practicing; 7) encouraging student questioning (to enable diagnostic assessment), were identified. We translated these seven strategies to the present design to promote conceptual learning. To ensure that students really learn collaboratively, that is to say there indeed is positive interdependence, individual accountability, equal and successful learning opportunity, and group processing in group collaborative work (Arends, 2004; Davidson & Worsham, 1992; Slavin, 1990a; Slavin, 1995), Students Team Achievement Division (STAD) was employed in the learning activity design. This collaborative strategy, highlighting heterogeneous grouping, class-level teaching, team study, individual testing, group recognition and rewarding, has been widely applied and proved effective in addressing well-structured problems.

3. Research Design

3.1 Participants

A fifth-grade class consisted of 27 students (14 boys and 13 girls) from a local primary school in Northern Taiwan participated in this study. The students were distributed into small groups of 3 to complete collaborative learning tasks. In grouping, heterogeneity in terms of student mathematics ability and gender was pursued. We first categorized students into High ability, Medium ability and Low ability groups based on their scores in the school mathematics test administered before the intervention. Then we randomly selected one student from each category to form a group. Altogether, 9 heterogeneous groups were composed. During intervention, the researcher shouldered the role as the teacher to ensure proper delivery of the lesson (the lesson was designed by the researcher). Being comfortable and competent in teaching with the collaborative technology (GS 2.0) and having rich experience in teaching mathematics in primary schools, the researcher was fully capable of instructing the lesson.

3.2 GS-supported collaboration

In this learning design, student collaboration was supported by both F2F communication and GS-based interaction. In GS lessons, students each were provided with a laptop with GS 2.0 installation. To encourage F2F interaction, students were seated in close physical distance. GS 2.0 user interface presents a two-paned window. The lower-pane is the private working space, the "private board" and the upper-pane is the shared working space, the "public board" (Figure 1). Users generate virtual pads of "scribbles" on the private board to draw, write and type in their ideas. All the actions enacted and all the contents displayed on "private board" are invisible to others. Scribbles crafted are shared and made public as users drag them onto the public board which is synchronized among all learning devices.

Scribbles on public board could be moved, deleted, and withdrawn to private boards for further revision. Users can select the group board that they want to visit and review by clicking the bottom on the right corner of the interface. The most striking feature of the GS technology is its synergy of autonomous cognition (on private board) and collaborative cognition (on public board). It also supports seamless switch between individual, intra-group, inter-group, and class level interaction. GS is highly customized as users can upload pictures, texts, movie clips and audios on the public board to scaffold teaching and learning. In this study, factor problems to be solved were presented in this area. Before participating in the GS lessons, all the students had undergone one session (40 minutes) of GS technical training during which they gained mastery in using the technology and developed familiarity with their group mates.

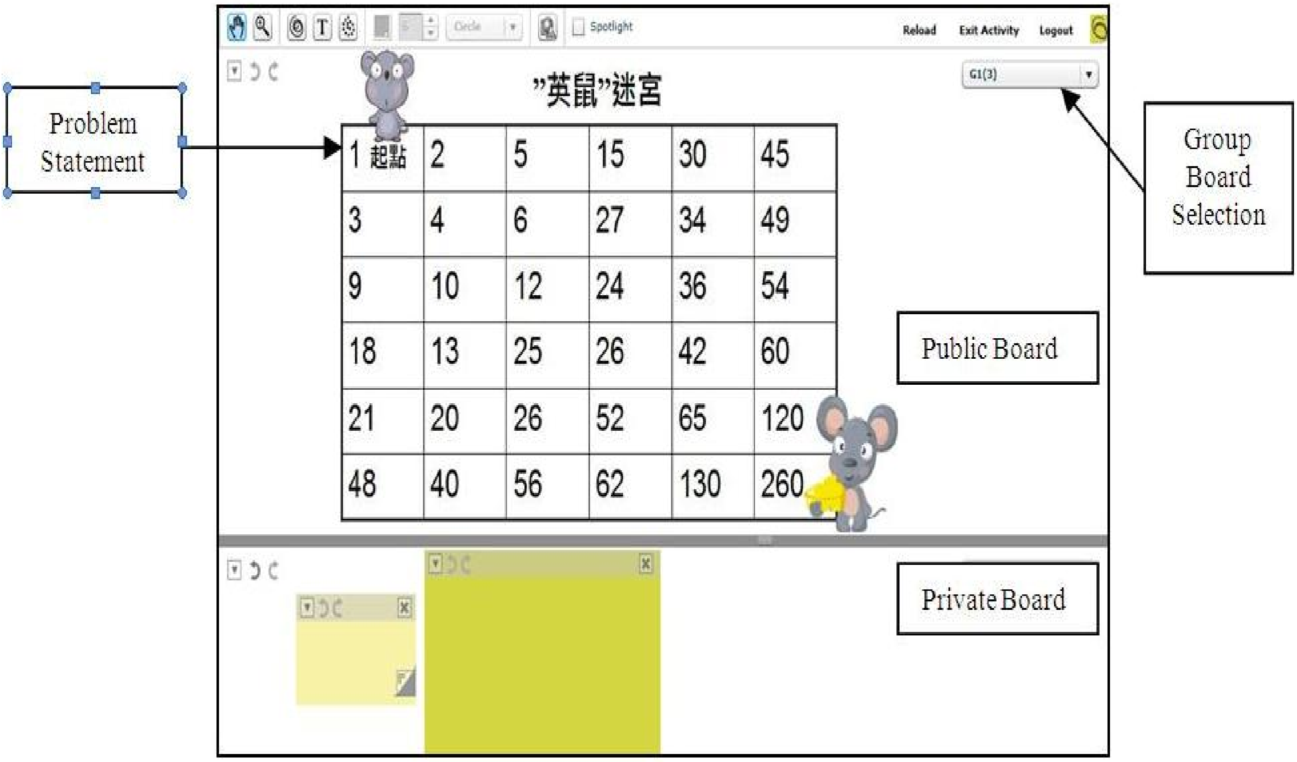

Figure 1. GS interface

3.3 Collaborative learning activity design

As aforementioned, in collaborative learning activity design, both concept instruction strategies and a collaborative strategy (STAD) were incorporated. The lesson designed was altogether 80-minute long involving three main learning activities. At the beginning of the lesson, the instructor spent 5mins introducing students the learning tasks, after which students engaged in a 15-minute reviewing activity, a 40-minute concept learning activity and a 20-minute concept application activity (see Table 1 for the detailed lesson plan) during which they gradually developed the concept of factor. The reviewing activity aimed at activating students' prior knowledge on operations (multiplication and division) that serves as a prerequisite for developing the concept of factor. In the concept learning activity, the main learning stage, two contextualized and situated problems were presented and solved via group work. In this process, students gained initial understanding of the factor concept via self-initiated exploration and collective cognition. Based on these initial ideas, the teacher further explained, elaborated and extended the concept. In the concept application activity, a game-based problem was incorporated to encourage student applying the developed concept to address real-world problems. The incorporation of gaming element could also enhance student learning motivation and interest.

Table 1: GS lesson design

Activity Flow	Instructional strategies
1. Task introduction (5 mins): Teacher provided general explanations on task requirements (finishing the problems presented via group work) and group rewarding.	
2. Reviewing activity (15 mins): Teacher explained the task requirement Students worked in small groups to solve two operation problems Class discussion Group rewarding	✓ Reviewing and activating prior knowledge ✓ Providing timely explanation to and elaboration on word-problems ✓ Highlighting operations and verification in learning and practicing
3. Concept learning activity (40 mins): Teacher explained the task requirement Students worked in small groups to solve two word-problems & verify the solutions Group working sharing Teacher summarized and commented on students' group work Teacher explained, elaborated and extended the factor of concept Group rewarding	✓ Engaging contextualized and situated learning materials and experiences ✓ Integrating hands-on experiences ✓ Encouraging student questioning
4. Concept application activity (20 mins): Teacher explained the task requirement Students worked in small groups to solve a game-based problem Group work sharing Class discussion & rewarding	✓ Engaging gaming ✓ Providing diversified learning and teaching materials

4. Data Analysis & Results

To assess student conceptual learning gains, Paired-Sample T test was conducted to see whether there was significant progress in student scores in the factor test after the GS lesson. Data analysis results proved students learning gains. Student scores in the post test were much higher than those obtained in the pretest ($t=-5.466$, $p< .01$) (Table 2). Moreover, the differences between students were narrowed after the GS lesson as the Standard Deviation decreased from 21.40 in the pretest to 11.98 in the post test. In the following, Paired-Sample T test was administered again to examine the retention of these learning gains. It was noticed that there was no significant difference between student post test scores and delayed test scores, though the delayed posttest was carried out one month after the post test ($t=1.700$, $p>.01$) (Table 3). From these statistical analysis results, the effectiveness of the proposed learning design in helping students learn mathematics concepts has been confirmed.

Table 2 :The Paired-Sample T test results (pretest vs posttest)

Variable	No. of students	Mean	Standard deviation	t	Significance
Pretest	27	68.85	21.40	-5.466	.000***
Posttest		86.99	11.98		

***p＜.0001

Table 3: The Paired-Sample T test results (posttest vs delayed test)

Variable	No. of students	Mean	Standard deviation	t	Significance
Post test	27	86.99	11.98	1.700	.101
Delayed post test		83.48	17.44		

To identify what types of students may benefit and benefit most from this learning design, we analyzed the effect of student mathematics ability on their achieved learning gains. Paired-Sample T test affirmed that, all the three categories of students-- Low ability students (t=-.4555, p< .01), Medium ability students (t=-3.531, p< .01) and High ability students (t=-2.384, p< .05) improved significantly in the post-test (Table 4 ~ Table 6). This further validated the benefits of our learning design to all the students in terms empowering learning.

Table 4: Paired-Sample T test (pretest vs posttest): Low ability students

Variable	No. of students	Mean	Standard deviation	t	Significance
Post test	9	45.013	13.453	-4.555	.002**
Post test		75.213	11.538		

** p＜.01

Table 5: Paired-Sample T test results (pretest vs posttest): Medium ability students

Variable	No. of students	Mean	Standard deviation	t	Significance
Post test	9	75.214	13.927	-3.531	.008**
Post test		91.168	6.918		

** p＜.01

Table 6: Paired-Sample T test results (pretest vs posttest): High ability students

Variable	No. of students	Mean	Standard deviation	t	Significance
Post test	9	86.326	9.245	-2.384	.044*
Post test		94.588	6.715		

* p＜.05

Further analysis was performed to find out what type of students might benefit most from this learning design. In practice, we ran an ANCOVA test (using student pretest scores as the covariant) to compare the performances of students of different mathematics ability in the post test. The assumptions of the analysis were met as the homogeneity of regression coefficients was achieved (F= .748, p> .05) (Table 5). The ANCOVA result showed that three types of students did performed significantly different in the post test (F= .232, p < .05) (Table 7). Post hoc test (LSD) found that there was no significant difference in post test scores between students of High ability and those of Medium ability (p> .05). However, students of Low ability performed strikingly different from those of High ability (p< .05) and Medium ability (p< .05) (Table 8). This result suggested that it was the Low ability students that improved most in this type of conceptual learning. This was probably the reason why the standard deviation was small in the post test compared to the pretest.

Table 7: ANCOVA test results

Source	Type III sum of squares	df	Mean Square	F	Sig.
Student Mathematics ability * Pretest score	120.237	2	60.119	.748	.486
Error	1688.386	21	80.399		

Source	Type III sum of squares	df	Mean Square	F	Sig.
Student Mathematics ability	610.383	2	305.192	3.881	.035*
Error	1808.623	23	78.636		

p< .05

Table 8: LSD test results

Student Mathematics ability	Average difference	Standard error	Sig.
High ability * Medium ability	3.432	4.484	.452
Low ability * High ability	-19.420	7.342	.014*
Low ability * Medium ability	-15.988	6.078	.015*

$p < .05$

5. Conclusion

This paper reports the design of a GS-supported collaborative learning environment to empower students' conceptual learning in the primary mathematic classroom and the investigation of the effectiveness of the learning design through evaluating students' learning gains. Through analyzing both "product" and "process", "objective" and "subjective" data, we were pleased to find that the proposed design could help enhancing student learning experiences.

In examining students' learning gains, a pretest-posttest-delayed posttest design was employed. In analyzing student test scores in a self-designed and validated factor test after the intervention, significant progress was noticed and successfully preserved as indicated in the delayed posttest. Moreover, further analysis showed that the proposed design has a general positive effect on all the students. Students, regardless of their mathematics ability, all gained better scores in the post test after the GS lesson. And it was the Low ability ones who improved most. In addition, the investigation of students' attitudes data also confirmed that this learning design could empower their learning. In accordance with the appeal to shift the focus from analyzing learning outcomes to learning processes analysis in CSCL research, the examination of student learning behaviors was also performed to further legitimize the design. Fine-grained analysis showed that students mostly demonstrated positive interactional behaviors in their group work. Individual cognition and teacher-student interaction was scarce.

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