A COLLABORATIVE CROSS NUMBER PUZZLE GAME TO ENHANCE ELEMENTARY STUDENTS' ARITHMETIC SKILLS

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ABSTRACT
In traditional mathematics education, students have typically been asked to solve lots of tedious and uninteresting exercises for developing the arithmetic skills of addition and subtraction. The paper provides an account of learning arithmetic skills in a more interesting way through the collaborative playing of a puzzle game. 83 students in three classes in Grade 4 were asked to solve arithmetic problems with three different methods: via playing an adapted "cross number puzzle" game on Group Scribbles (GS) collaboratively, via playing the same game on GS individually, and via the traditional method of teaching and learning, i.e. with no games at all. Analysis of the pre and post learning achievement data reveals that the two classes who played the game performed better than the control class, with the collaborative class students achieving better than the individual class students. By playing the game, low-ability students, in particular, made the most significant progress in arithmetic capability and in building up their confidence in doing arithmetic calculations.

INTRODUCTION
Arithmetic skills in addition and subtraction are an important basic component in any mathematics curriculum for young children. We were interested in designing a simple yet fun digital game to enhance the learning of students. Our game takes the form of a cross number puzzle game to help young students learn and practice arithmetic skills in the formal mathematics curriculum in school. This adapted version of the "Cross Number Puzzle" runs on a technology platform called Group Scribbles. The game promotes the concept of addition and subtraction, and enhances children's capacity to build up their arithmetic skills progressively. We conducted a study with three classes of students, namely, traditional class learning serving as a control group, a class of students learning individually on GS, and a class of students learning collaboratively on GS, and analyzed the learning efficacies of these three groups. We also explored different collaborative learning patterns that involved students working together on solving arithmetic problems among those two classes doing collaboration.

Game playing is one learning strategy which is being actively researched. Research has shown that if games are embedded in education, it can motivate students and promote their willingness to learn (Coble, 1977). Aufshnaiter, Schwedes & Helankom, (1984) pointed out the "game-oriented pedagogy" can lead to amusing and fun activities to enhance teaching and learning. Effective learning performance can result from the projection of feeling and action into impersonal conceptual structures in the process of advancing skills of problem solving.

Many educators have classified operating addition and subtraction problems into four problem types: change, combine, compare and equalizer (Carpenter, Hiebrt & Moser, 1981; Fuson, 1992). English (1998) points out that change and combine are easier while take-away and compare are more difficult challenges for elementary school students. In an arithmetic equation, any of the three numbers could be the unknown number. We adopted this widely used method in our study. Fuson (1992) defines these three types of "change" (placeholder) as: Missing End, Missing Change, and Missing Start. Van de Walle (2001) also classifies the type of "change" into three types: result-unknown, change-unknown and initial-unknown. These three types of problems present different levels of difficulty to the students. In Thompson's study (1983), the initial unknown is most difficult. If the student applies the direct modeling strategy by using counters or tally marks to model directly the action or relationships described in the problem (Carpenter et al., 1993), he or she always does not know how many counters to be put down to begin with. Table 1 below illustrates the three levels of change types in story problems. Level I is when the result number is unknown, Level II is when the change number is unknown, and Level III is when the initial number is unknown (Carey 1991; Peterson et al., 1991).

Table 1: Three levels of "Change" types in problems

Change Types	Join	Separate
Result number unknown	Standard sentence: A + B = □	Standard sentence: A – B = □
Change number unknown	Standard sentence: A + □ = B	Standard sentence: A - □ = B
Initial number unknown	Standard sentence: □ + A = B	Standard sentence: □ – A = B

Design of game challenge level

Based on these three levels in Table 1, we designed our system in terms of five stages of problem posing to the students (Table 2):

In stage 1, the student is required to derive the answer of an arithmetic expression (result number unknown), inculcating the skills of basic addition and subtraction, for example: 3 ± 2 = □.
In stage 2, the arithmetic operator is removed. Students were required to understand the concept of arithmetic operator, for example: 3 □ 2 = 5.
In stage 3, the change amount is removed, for example: 3 ± □ = 5.
In stage 4, the initial amount is removed, for example: □ ± 3 = 5.
In stage 5, both the initial and the change number are removed. It is more difficult with most changes, as here the sentence includes two variables: change amount and Initial amount unknown. For example: □ ± □ = 5.

Table 2: Level of difficulty in the design

Level of difficulty	Description	Example
Level 1	Result number unknown — basic skill practice	A ± B =□
Level 2	Remove operator — between basic skill practice and comprehension application	A □ B = C
Level 3	Change number unknown add-to or subtraction — comprehension application	A ± □ = B
Level 4	Initial number unknown add-to and subtraction — comprehension application	□ ± A = B
Level 5	Change number unknown and Initial number unknown, addend or summand type — the most difficult level	□ ± □ = A

The questions in cross number puzzle game are designed based on the national curriculum in Taiwan. Lewis et al.（1997）showed that most students could not find and understand the solution by backtracking or trial and error. Teachers should construct the connection between the mathematical concepts and the practical operations. In the light of the studies of Kieran (1992) and Lewis et al. (1997), we invited an experienced mathematics teacher to articulate a solution strategy using the unknown number mapping table (Table 3).

It lists the strategies in each difficulty level. Symbol "○" means this strategy can be applied at the level, while "×" means cannot. For example, in level 1, the student can use "counting number" with hers finger one by one or mental computing to get the right answer. Others strategies can not be applied at this level. At level 2, the student can obtain the answer by guess and estimation or "counting number". "Counting number" is the basic strategy which could be applied at all levels.

"Trial and error" means randomly select a number to replace the unknown number to seek the right answer. Strategies like "Undoing", "Shift item" work at level 3 and level 4. Problems at the most difficulty level (level 5) have two unknown numbers possibly with more than one solution. The student can use all strategies to solve problems spanning level 1 to level 4.

Table 3: Solution strategy of unknown number

Operation structure	Difficult Level	Strategy to get answer				
		Trial and error (guess and test)	Number counting	Undoing	Shift item	Balance
5 ± 4 = ?	1	×	○	×	×	×
5 ? 4 = 9	2	○	○	×	×	×
5 ± ? = 9	3	○	○	○	○	○
? ± 5 = 9	4	○	○	○	○	○
? ± ? = 9	5	○	○	○	○	○

Note: ○: Working, ×: Not working. Difficult level is designed from table 2.

DESIGN OF THE FEEDBACK SYSTEM

A feedback mechanism was introduced to the game design in this study. Feedback is considered to have strong impact on the learning process and result (Kulhavy & Stock, 1989; Balacheff & Kaput, 1996). Appropriate feedback can lead the learners to focus on key elements of learning. The learner can always adjust their learning strategies to try to close the gap between their actual performance and the goal. They reflect on their learning by a self-monitoring feedback loop. Hence, they can change their learning strategies in the follow-up learning and seek a better way of learning (Alexander & Shin, 2000).

According to Roblyer (Roblyer, 2004), in repeating drill-and-practice activity, some elements should be considered: Control the speed of practicing-student need understand meaning of question and feedback timing. Feedback after correct answer-provide feedback message to student after student response the right answer and feedback should clearly understand and to motivate student learning. Reinforce the right answer- avoid counter effective to student, avoid student get more exciting from wrong answer's response message. Based on the 3 things: speed, feedback and reinforcement, should be considered in feedback designed in this study.

Schmidt (1991) proposes that feedback is the result of a series of actions. It represents the personal response or reaction to the information they received. The feedback itself is a problem solving process that checks the performance of action to improve a person or a group. In technology-enabled learning, feedback is typically provided as messages shown to students after their responses (Cohen, 1985). Siedentop (1991) points out that feedback can promote the interaction between the teacher and the learners. Teachers can give feedback to students in terms of their actions and performance, which enable them to know or to amend their understandings and may boost their enthusiasm for learning (Keh, 1992).

There are three forms of feedback: immediate feedback, summary feedback and compromise feedback (Schmidt & Wrisberg, 2000). Collins, Carnine, & Gersten (1987) point out three levels of feedback messages: little feedback- just show the answer is right or wrong; basic feedback- if answer is not correct then show right answer; and descriptive feedback- give some hints to learner, to drive right answer. Descriptive feedback can promote the motivation to challenge new tasks and new problem. The feedback mechanism provided by software systems mainly involves getting the right answer or the direction of goals as summarized by Sales (1998). These are: no feedback, knowledge of response, knowledge of correct response, answer until correct, and elaboration feedback. In our study, we rebuild feedback flow based on previous study. in the feedback flow. Feedback procedure is under different condition of property response different feedback message. The feedback mechanism flow is shown in Figure 1.

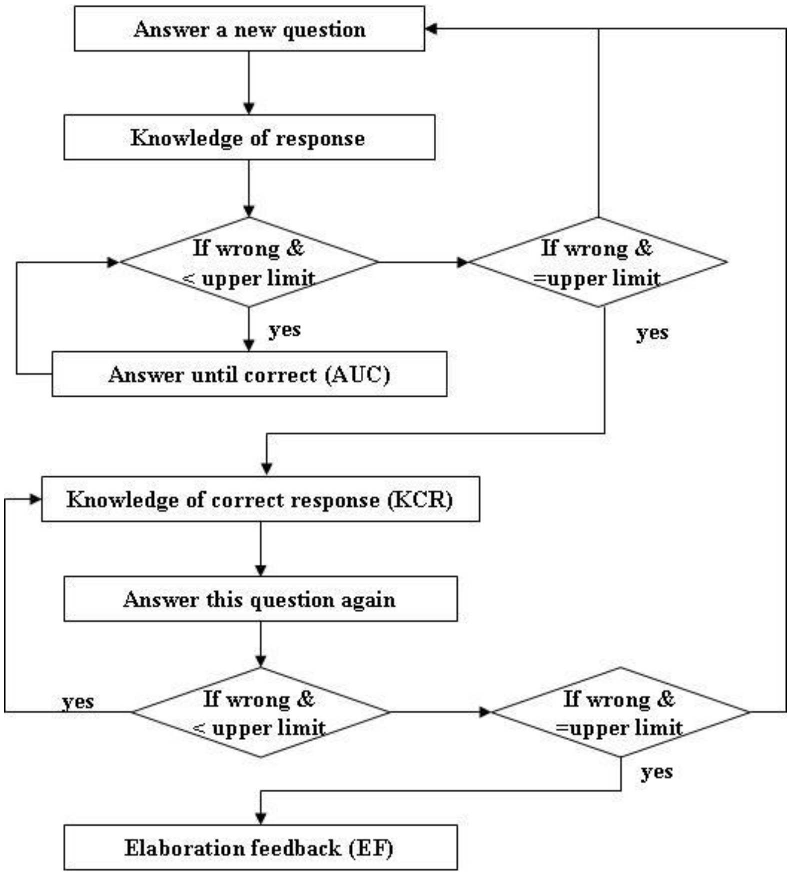

Figure 1. Flow of feedback mechanism

METHOD

A cross puzzle game was embedded in the Group Scribbles system which was used in our research for two classes of students. It was not offered to the third class of students which serve as the control class. This experiment includes pre-testing, teaching activity, post-testing, questionnaire and interview for four weeks. And we only study the learning outcome of addition and subtraction, others capabilities are not included. In this experiment learning performance and confidence will be tested by statistical examination.

Participators

Eighty three students in Grade 4 (ages 10 or 11) participated in our study. They learned some basic addition and subtraction since Grade 1 but they needed to connect them to the new concepts and skills required for Grade 4 mathematics. In this research, we explored the effects of "Cross number puzzle" game applied in learning, which was designed to provide the feedback mechanism. We had three experimental classes (shown in table 3): students in Class A played the "Cross number puzzle" game in small groups, and students in Class B played the game individually. Class C is the class doing traditional learning (a control class). Students in Class A and B were grouped according to their average scores of the previous three tests in the current term. Using percentile ranking, those students with the percentile rank of score over 73% were classified as high-math achievers; those with percentile rank of score between 27% and 72% were classified as medium-math achievers, and those with percentile below 26% were classified as low math achievement. Students in class A were divided into homogeneous groups with three per group. 6 students in the high-achiever group forming two groups. Three medium-achiever groups included 9 students and another three low-achiever- groups of 9 students separately.

Table 3: Experiment participators

Class	Type	Grouping Number	No. of students	Sum	Total
Traditional Learning (Class C)	Whole class teaching	No	31	31	31
Individual Learning (Class B)	High-achiever	No	8	8	28
	Medium-achiever		12	12	
	Low-achiever		8	8	

Collaborative Learning (Class A)	High-achiever	G1	3	6	24
		G2	3		
	Medium-achiever	G3	3	9	
		G4	3		
		G5	3		
	Low-achiever	G6	3	9	
		G7	3		
		G8	3		

Group Scribbles System

We utilized Group Scribbles (GS) as the platform for the game, and conducted analysis of the collaborative work within these groups. GS is a computer-supported collaborative learning system developed by SRI International to conduct small-group collaborative concept mapping activities (Chaudhury et al., 2006; Looi, Chen & Ng, 2010). Each student has a Tablet PC which the screen was divided into upper and lower frames (Figure 2). The lower frame is for individual cognition, that is, the student sketches or types his/her answer individually. The upper frame is a shared space (public board) in which the students show all of their individual answers, and work together as a group. They can even check the work from other groups by clicking the button on the top right corner (Figure 2). The teacher can monitor their process of learning and provide appropriate guidance.

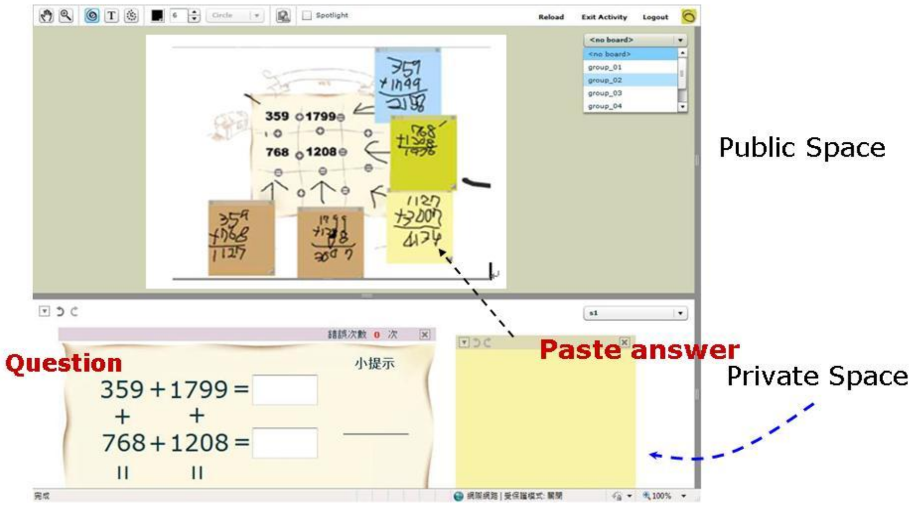

Figure 2. Spaces for individual and public cognition work

Figure 2 shows the interface of "Cross Number Puzzle" in GS. The questions are designed ranging from the easy to the difficult in terms of the five levels of difficulty. When the students complete the calculation, they can fill in the answer box and press OK button under the question area to submit. If the answer is correct, there will be a brief description of the key points. If the answer is wrong, the system will generate and display step-by-step hints based on the number of errors from the user inputs (Figure 7). The action repeats until the maximum number of errors reaches the upper limit. Then the system will show the correct answer and the methods of problem-solving. Four different types of questions were shown below (Figure 3 to Figure 6) in the "Cross Number Puzzle" and one case of an individual calculating process with wrong answers and hints.

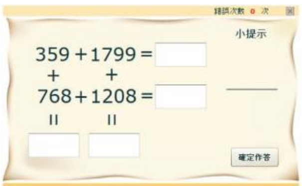

Figure 3. Question type 1

Figure 4. Question type 2

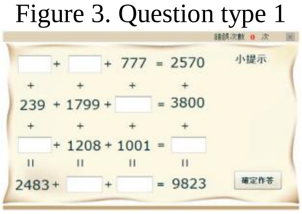

Figure 5. Question type 3

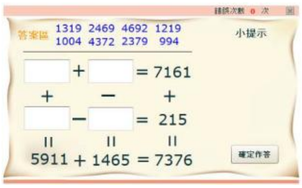

Figure 6. Question type 4

Figure 7. Hints

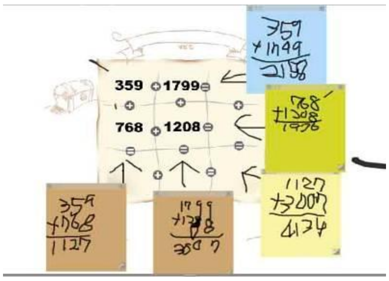

Figure 8. Calculating process

Figure 8 provides the screenshot of the calculation processes in a four-member group, in which each individual pasted his/her sketches in different color.

Procedure

The study for three classes lasted for four weeks. In the first week, a session for 30-minute pre-test and 20-minute training was administered. Students were asked to familiarize with GS system and the operation of the game by doing simple exercises. In the second week, the game was played in one lesson lasting for 60 minutes, followed by a 30- minute post-test and a 20-minute questionnaire in the third week. In the fourth week we did interviews to the teachers and students. A pre-activity and three formal learning activities were included in this study. The pre-test and post-test had the same questions but the questions are ordered differently.

In the game playing session, a pre-learning activity and three learning tasks were designed and implemented in Class A and Class B separately. Students were asked to fill in the operator in an arithmetic equitation in activity 1. Activity 2 is about filling in the unknown number while in activity 3 students were asked to estimate and trial-and-error methods to solve the problem. The only difference of these two classes was students in Class B played the game individually but students in Class A played it collaboratively. Figure 9 below gives an example of a game screenshot of a collaborative group with four members. Group members could use private board for sketches and confirmatory calculation. They could post their sketches or results to the public board.

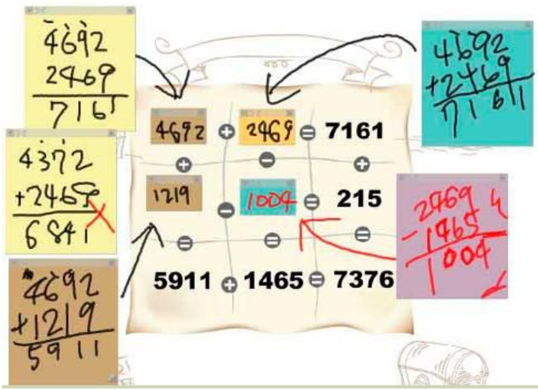

Figure 9. Example of Change number unknown and initial number unknown exercise

Findings

We analyzed students' scores in the pre and post-tests, collected questionnaires, video-taped their activities in classes, and tracked their screens during the process of game playing. Results were analyzed to look at the use of games to build arithmetic skills, collaborative patterns and how feedback was used in gaming.

Results of the assessment of arithmetic skill ability

We administered pre-tests and post-tests and performed independent sample t-test of three classes on their results. Table 4 shows the pre and post test results of Class A, B, and C. Students in Class A also have the highest average score in the post-test. Their average increased by 13.00, from 50.29 in pre-test to 63.29 in post-test ($p=0.002<0.01$). This indicates students in Class A progressed more than those students in Class B through playing the game collaboratively. Traditional class C made no significant improvement.

Table 4: Pair T-test of Pre and post tests

Tests		Pair t-test						
		Min.	**Max.**	**Average**	**SD**	**Progress**	**t**	**p**
Class C	Pre-test	28.34	86.68	58.35	9.73	0.01	0.049	0.961
	Post-test	25.01	93.35	58.36	11.184			
Class B	Pre-test	20.00	93.35	53.83	11.210	5.13	2.908	0.008*
	Post-test	13.34	100	58.94	11.399			
Class A	Pre-test	6.67	76.68	50.29	12.078	13.00	3.403	**0.002****
	Post-test	16.67	100	63.29	12.770			

*P<0.05, **P<0.01

Further observation of these collaborative groups implied that the low math-achiever students made the most significant progress, which can be easily gathered from the following table. Analysis of Table 5 and Table 6 showed that the low-achiever groups in Class A had the highest increase in post-test scores with high level of significance (P=0.001). This indicates that the low-achievers of these collaborative groups derived the most benefits in this study.

Table 5: T-test of pre and post tests in collaborative class

Number of Participants (N=24)	**t-test of collaborative class**							
Tests	**Number of Participants**	**Min.**	**Max.**	**Average**	**SD**	**Progress**	**t**	**p**
Pre-test of high-achievers	6	63.34	76.68	70.56	3.141	7.22	1.308	.248
Post-test of high-achievers		48.34	100	77.78	10.576			
Pre-test of medium achievers	9	45.01	66.68	56.48	5.182	6.47	.880	.404
Post-test of medium-achievers		40.01	98.35	62.96	14.454			
Pre-test of low-achievers	9	6.67	55.01	30.56	10.111	23.33	4.834	**.001****
Post-test of low-achievers		16.67	76.68	53.89	9.874			

Further analysis from Table 6 found that low-achievers and medium-achievers made more progress than high-achievers; there is obvious evidence that low-achievers made the most improvement in the individual class. It should be noted that two students' data were deleted from the data set of Individual Class, because one low-achieving and one medium-achieving student's scores were found to decrease dramatically on the post-test. Reviewing the interview and questionnaire data proved that these students did not like enjoy reading and did not pay attention to any feedback messages was given during game play.

Table 6: T-test of pre and post tests in individual class

Number of Participants (N=28)	**t-test of individual class**							
Tests	**Number of Participant**	**Min.**	**Max.**	**Average**	**SD**	**Progress**	**t**	**p**
Pre-test of high-achievers	8	53.34	93.35	71.06	8.070	1.04	.407	.696
Post-test of high-achievers		51.68	100	72.10	8.013			
Pre-test of medium achievers	11	21.67	80.02	48.16	9.502	5.55	.2.490	.032*
Post-test of medium-achievers		21.67	85.02	55.00	11.437			
Pre-test of low-achievers	7	20.00	60.01	43.08	9.245	5.21	2.657	**.046****
Post-test of low-achievers		26.66	75.02	48.03	11.112			

Table 7 shows further analyses conducted on three different types of test questions on “addition and subtraction” on low achievers in collaborative class. Students had better scores in all three types of questions in the post-test. But the low-achiever groups achieved significantly highest improvement in questions of “basic computing”, “unknown constant” and “Cross Number Puzzle” with the increase of average score 9.63, 7.38 and 6.32 respectively. This suggests that these low-achievers benefited the most from the “Cross Number Puzzle” in improving their basic arithmetic skills.

Table 7: Low achieved students’ progress in Pre and Post tests in collaborative class

Low achievers in Class A (N=9)		**Pre -test**	**Post - test**	**Average increased scores**	**Ratio of progress in different questions**
Basic computing skills	Score of question 1 to 5 （33.33）	18.52	28.15	9.63	41.3%
Unknow constant	Score of question 6 to12 （46.67）	8.90	16.28	7.38	31.7%
Cross number puzzle	Score of question 13 to 15（20.00）	3.14	9.46	6.32	27.0%

The average score of Class B (the individual group, shown in table 4) is 4.17 higher in the post-test (57.21) than in the pre-test (53.04) at a significant level of .026 ($p<0.05$). This indicates that learners also made progress through playing the game. To gain further insight into the differences between the improvement between the individual class and the collaborative class, regression analysis was performed to study the relationship between the scores of pretest (as the independent variable) and the score of post-test (as the dependent variable) within both classes. The results of F-test for pre-test ($F = 2.487$, p =. 121, $p> .05$) shows that the individual group (Class B) and the collaborative group (Class A) can be regarded homogeneous.

However, Table 8 below provides the result of F-test ($F = 4.479$, p =. 039, $p <.05$), which is significant at the $p<.05$ level. The striking result to emerge from the data is that the collaborative class had much greater improvement than the individual class in this study although they played the same game.

Table 8: ANOVA for individual class and collaborative class

Analysis of variance for Class A and Class B					
Item	Sum of squares	DF	Mean Square	F value	Sig.
Inter-group	313.995	1	313.995	4.479	.039*
In-group	3434.814	48	70.098		

Feedback usage in Class A and Class B

As we mentioned before, students in Class A played the game collaboratively in groups while students in Class B completed the game individually. We can easily conclude from Table 9 below that feedbacks in the form of “Hints” were much more frequently used in Class B than in Class A. It suggests that when students encounter problems and difficulties but without other people’s help, he or she would search help from the “feedback” system. On the other hand, students in Class A would discuss their strategies to solve the problem within a group first, allocating cooperative work among group members. They only referred to the “feedback” system when all students in the group were uncertain or in a dilemma. They used the “Hints” less often then students in Class B. However either in Class A or Class B, high-achiever students seemed to have used the “feedback messages” far less than low-achiever students. Low-achiever students relied more on feedback.

Table 9: Feedback usage in Class A and Class B

Number of use in different group	**Class A (N=24)**	**Class B (N=28)**
High-achiever	0.54	0.84
Medium-achiever	0.71	1.31
Low-achiever	1.25	2.09
Average usage	0.86	1.40

Further observations were made concerning students’ collaborative activities (in Class A) in the process of game playing, which includes three learning activities to be completed in the game.

Pre-activity: Result number unknown

Before formal learning activities, a pre-activity was executed, two objectives in this activity: familiar system operation and warm up student's calculation. The question model is A ±B =□ which is the level one difficulty- a basic skill in arithmetic. There were 23 of 24 students in collaborative groups who finished this activity. If students can finish this activity, they will have ability to play next three activities.

Learning activity 1: Remove the operator

Four different patterns of collaborative problem solving were found in their activities of "remove the operator": whole-group-deciding, two-member-deciding, leader-deciding and individual deciding. Group 6 made the decision by all group members. Three groups, Group 1, Group 3 and Group7 decided the answer individually. Two groups took the two-member deciding pattern and the rest two groups took leader-deciding pattern. The following figures (Figure 11 to Figure 14) shows different layout of the game in different collaborative methods. For example, in figure 11, three students in group 6 (one student in one color of "+") post their answer as 4777 +++ 4611 +++ 1799 = 11154, six "+" and one "=". All these three students operate the addition correctly. Therefore we could judge that this group's answer was decided by the whole group. In figure 13 there is only one answer being pasted, when we referred to the video recording, we found this group was absolutely leader-deciding.

Figure 11. whole-group-deciding

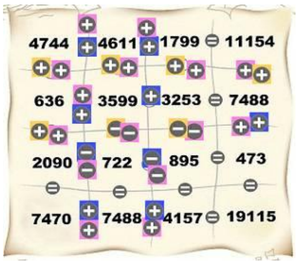

Figure 12. two-member-deciding

Figure 13. leader-deciding

Figure 14. individual deciding

Learning activity 2: Filling in the Unknown Number

To enable learners get the unknown number in the puzzle by observing, calculating those given numbers and estimating the result, for example , A ± □ = B & □ ± A = B, tasks division and coordination were necessary in one group. From the procedural layouts of the game on the screen we got some insights of methods of students' collaboration and their strategies to complete the calculation. The results were shown in Table 10.

Table 10: Methods of collaboration in Class A (8 groups)

Methods	**Description**	**Group**	**Ratio of different method used**
Individual calculation	Group members did the calculation by themselves individually. Little collaboration occurred.	G1,G2	25.0%
Comparison	Started from different thread and compare each other's result at the intersection	G3,G5	25.0%
Relay	One finish one section and another take over to continue calculating	G4	12.5%
Assisted calculation	One of the group members is in charge of all calculation and other members checking his/her calculating process	G6	12.5%
Through-out calculation	Some members calculate from the beginning to the end and other members calculate from the end to the beginning then they compare at the intersection.	G7,G8	25.0%

Comparing Tables 10 and 11, we identify the most interesting learning strategies: most medium-achievers group used the method of cross calculation, and high-achievers seemed to prefer individual calculation.

Learning activity 3: Fill in the Multi-unknown Number

This most difficult task (Level 5), students would fit in multiple unknowns' equation like □＋□＝C or □－□＝C.

By tracing the working path and the group's problem solving strategies, we found that cross calculation is the most favorite, which was used by 50% of groups. The following table summarizes the group strategies used.

Table 11: Methods of collaboration in Class A (8 groups)

Methods	Description	Group	Ratio of different methods used
Individual calculation	Students did the calculation by themselves individually.	G1	12.5%
Cross calculation	Students started from different paths and compare each other's result at the intersection	G2,G3,G4,G5	50.0%
Reverse calculation	Some members in the group calculated from a vertical or a horizontal path, other members calculated from the result to get the answers.	G6,G7,G8	37.5%

Teacher's voice

Teachers also noticed better collaborations in Class A. Students of Class A were motivated and had good sharing in their group tasks:

> "Most students were encouraged to have more discussions in this class. One of the high-achiever groups had conflicts during the discussion because everybody exhibited high confidence and expectation. Another medium-achieving group showed great enthusiasm in collaborative learning with one of them playing the role as a leader. "

> "Every student in Class A could get feedback from the system as well as from other members. The consensus achieved in the group made the whole class improve. However in Class B, students had great diversity in their responses. Some students produced good responses when they understood but for some others, they were not sure and thus they talked with their neighbors. And some of them just immersed themselves in individual work and require the teacher to guide them when they encountered difficulties."

Findings from the post-questionnaire

A post-questionnaire of the experiment was administered and analyzed according to Likert's five-point scale standard (Strongly agree, agree, Neutral, disagree and strongly disagree). We investigated the five facets of the experiment to analyze the students' perceptions and experiences in the Cross Number puzzle activities in Class A and Class B and found positive results, as seen in table 12.

Table 12: Findings from questionnaires

No.	Question	Class	Mean	Sig.
System functions				
Q1	I can use function of sketch: paste, move, writing	Individual	4.07	.001**
		Collaborative	4.83	
Q2	This system is easy to operate	Individual	3.79	.003**
		Collaborative	4.54	
Q3	I feel the flow of wireless connectivity is fluent and not slow	Individual	3.79	.144
		Collaborative	4.25	
Q4	It is very easy to use touch-pen to write down the steps in the calculations	Individual	4.25	.092
		Collaborative	4.63	
Feedback usage				
Q5	I will check the system "Hints" when my answer is wrong	Individual	4.25	.454
		Collaborative	4.46	
Q6	The hints from the computer enable me to think in a different way	Individual	4.32	.249
		Collaborative	4.63	
Q7	The hints from the computer motivate my calculations	Individual	4.14	.124
		Collaborative	4.58	
Q8	The hints from the computer can correct my wrong concepts	Individual	4.32	.185
		Collaborative	4.67	
Q9	The hints from the computer can help me learn	Individual	4.14	.087

	better	Collaborative	4.58	
Engagement				
Q15	I can complete all activities and answer all questions	Individual	4.04	.002**
		Collaborative	4.79	
Q16	I will try all possible solution methods	Individual	3.64	.001**
		Collaborative	4.63	
Q17	I hope to do more cross number puzzle games in my mathematical lesson	Individual	4.71	.030
		Collaborative	4.92	
Learning attitudes				
Q18	I like this kind of discussion in mathematical lesson	Individual	4.00	.000**
		Collaborative	4.79	
Q19	I think this game will let me have more confidence in mathematical learning	Individual	3.93	.000**
		Collaborative	4.79	
Q20	I will spend more learning time in this puzzle game	Individual	3.96	.096
		Collaborative	4.46	
Q21	This activity will let me understand the operations involving the unknown number	Individual	4.04	.002**
		Collaborative	4.79	
Q22	I think by computer-based learning helps m understanding more than traditional classroom teaching	Individual	4.46	.015*
		Collaborative	4.92	
Q23	I can focus in learn mathematics in this number puzzle learning activity	Individual	4.43	.007**
		Collaborative	4.88	

(1) System functions: The mean of Question 1 and Question 2 are (4.07, 4.83) and (3.79, 4.54) for collaborative and individual class. P-values are less than 0.01, suggesting that the students found the system easy to manipulate. But the average scores in the individual class are less than collaborative class. The collaborative class students can talk with members to understand system functions, and in the individual class, the students sought the teacher's help. This condition is also shown in Q3 and Q4.

(2) Feedback usage. The mean of the responses to the questions here are over 4 points which showed that feedback usage was helpful for students. These data support the previous finding about feedback usage in class A and class B.

(3) Engagement: The students were very engaged in the cross number puzzle and they attempted to explore all solution methods. Most of students in collaborative class wanted this puzzle system to be used in classroom learning.

(4) Learning attitudes: Both classes (A and B) showed positive attitudes towards this learning environment. The mean for the collaborative class students' confidence is 4.79 higher than that of individual class. Another statistical data before and after experiment was shown in Table 13, showing that 87.5% students in collaborative class had their confidence enhanced in this system. More than 80% of the participants stated that they liked to work with their group members to solve problems. Over 85% of them thought that they could easy understand arithmetical skills in game processing. It indicates that their strong willingness in learning through playing the cross number puzzle game and consequently they were fully motivated to learn.

Table 13: Confidence analysis before and after experiment

Confidence Analysis									
		Collaborative class (24)				**Individual class (26)**			
		Before experiment		**After experiment**		**Before experiment**		**After experiment**	
		Sum of students	**Percent**	**Sum of students**	**Percent**	**Sum of Student s**	**Percent**	**Sum of students**	**Percent**
Degre e	5	7	**29.2%**	21	**87.5%**	6	**23.1%**	9	**34.6%**
	4	8	**33.3%**	1	**4.2%**	6	**23.1%**	10	**38.5%**
	3	8	33.3%	2	8.3%	10	35.7%	7	26.9%
	2	0	0.0%	0	0.0%	2	7.15%	0	0.0%
	1	1	4.2%	0	0.0%	2	7.15%	0	0.0%
Max.		5		5		5		5	
Min.		1		3		1		3	
SD		1.007		.588		1.174		.796	

Mean	3.83	4.79	3.46	4.08
t-value	4.337		2.173	
P-value	**.000****		**.040***	

** p<.01 Degree: 5.strongly agree, 4.agree, 3.neutral, 2.disagree, 1.atrongly disagree

Collaboration

Table 14 shows that 85% students tried to do cooperation and discussion before they submitted the answer. There was one high-achiever student who did not discuss with others when he did his calculations. In the follow-up interview, he explained that he was quite confident and only shared his results with others when he completed all his calculations. 87.5% students claimed that it was much easier to complete the calculations with collaboration than to have to do it individually. Those students without confidence in mathematics found it easier to share their own ideas with others and co-complete the calculation. All students agreed that they derived benefits from discussion with other classmates.

Table 14: Questionnaires analysis in collaborative class

No.	Question	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Mean
Q10	I can find the right answer by group discussion	20 83.4%	2 8.3%	2 8.3%	0 0.0%	0 0.0%	4.75
Q11	I will discuss with my group member, then write down the answer	18 75.0%	2 8.3%	3 12.5%	1 4.2%	0 0.0%	4.54
Q12	Collaboration with group members will help me find the solution rather than myself doing it	21 87.5%	3 12.5%	0 0.0%	0 0.0%	0 0.0%	4.75
Q13	I will talk freely about my thinking in the group	20 83.4%	2 8.3%	2 8.3%	0 0.0%	0 0.0%	4.75
Q14	My communication with group members helps me in my learning activity	19 79.2%	5 20.8%	0 0.0%	0 0.0%	0 0.0%	4.79

DISCUSSION

This paper investigated the benefits of learning addition and subtraction through the game "Cross Number Puzzle" on Group Scribbles. Our observations and investigations of the two classes who played the game individually and collaboratively respectively showed some interesting differences. First, after statistical analyses these two classes have more improvement than traditional class. Between two classes use "Cross Number Puzzle" system; the collaborative learning groups (Class A) were found to have made greater progress than individual learning groups (Class B). It suggests that collaborative learning may have enhanced learning effectiveness. From the statistics, we can conclude the low-achiever in collaborative class' students benefited the most in this "Cross Number Puzzle" game. Further analysis of the low-achievers show that they made significant progress in "basic computing skills" has significant progress, thus suggesting that this puzzle game can help low-achieving students to improve their basic skill practicing. Collaboration also plays an important role in enhancing learning in Class A with the incorporation of the "feedback system" and collaboration strategies. After doing the practices in this puzzle game, the students in collaborative class built up more confidence than those in the individual class. Thus, this puzzle game system may have better performance in collaborative environment, but more experiments need to be carried out to verify this result.

High-achieving students can do individual practices to improve their skills. Although there is no clear evidence shown that high-achievers from the collaborative class benefited, we cannot yet infer that high-achiever students are not suitable for collaborative learning in "Cross Number Puzzle" system.

In both classes, the low-achiever students accessed the "Hints" most often while the high-achiever accessed the least. The individual learning groups in Class B had much higher frequency of access to "Hints". It indicates that the collaboration among group members in Class A did assist students' problem-solving. They relied less on the "feedback" system because they could get help from group members. However, in both classes, the low-achiever students had the highest demand for "Hints" for help.

About methods of problem solving: students in collaborative learning groups presented four different methods of problem solving in their activities of "removing the operator": whole-group-deciding, two-member-deciding, leader-deciding and individual deciding. In the activity of "fill in the figure in the expression," the students had five methods of calculations: individual calculation, comparison, relay, assisted calculation and through-out calculation. Students also showed four different ways of calculation: free calculation, calculate from the top, calculate from the bottom and calculate from both the top and bottom. They did the calculation in three different collaborative ways: each student calculates the whole thing him/herself; one student started from the top and the other started from the bottom; and they did backwards calculation for checking.

FUTURE WORK

Based on these findings in this study, we draw the following recommendations for future research.

More time on the "Cross Number Puzzle" learning activity: Our study has some limitations concerning the duration of the learning activities and the scale. For broader applicability, we need more experiments and a larger population of students to verify the findings of this current study.

Bigger screen for sharing: With a concern for the eyesight and health of young children, a big screen to display the public board for all group members could assist the discussion within a group by providing a focal point of attention. The individual board could still be retained in the screen of the students' personal Tablet PC for their private cognition.

Adaptive feedback: Although feedback system can help students, we only offered phased hints to students in this "Feedback system". The feedback only includes the general direction of calculation concept and the problem solving process. If system can diagnose and evaluate the individual student's errors, system can provide each student with the individual corresponding solutions or suggestions to fit his skills.

Incorporate a timer: From our analysis of the frequency of feedback in this study, a timer could be added to the system to record the duration of problem solving by each user and let game system more challenge. This would also enable the teacher to gauge the time used by the students at each stage of their problem-solving. But time constraint also could be a pressure increase difficult so an adjust timer controlled by teacher will be suitable.

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