LEARNING ENGLISH VOCABULARY COLLABORATIVELY IN A TECHNOLOGY-SUPPORTED CLASSROOM

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ABSTRACT
This study was intended to investigate whether computer-assisted collaborative learning is comparable with computer-free and individual learning; in particular, it examined each of their effects on learning English vocabulary, followed by an analysis of their behavior patterns. In a junior high school in northern Taiwan, a normal classroom was first equipped with an interactive whiteboard and seven all-in-one touchscreen desktop computers. All participants from three intact classes, 76 students in total, were asked to finish five review activities of the target English vocabulary and assigned to one of the following groups: the learning for the group of computer-supported collaboration took place in the technology-supported classroom whereas that of computer-free collaboration and that of computer-free non-collaboration in a normal classroom. The results of the vocabulary tests showed no significant differences among the three groups; those learning English vocabulary collaboratively in a technology-enhanced environment outperformed the other two groups in vocabulary retention. In addition, analyses of the group's behaviors before the touchscreen desktop computers echoed and explained their better performances than the other two groups.
Keywords: behavior pattern, collaborative learning, English vocabulary learning, technology-supported classroom

INTRODUCTION

With advancement in information technology, many novel ones, such as the electronic whiteboard and all-in-one computers, have been widely used for assisting instructional activities. These technologies not only facilitated the learning effects but also increased students' interest in learning (Schmid, 2008; Smith, Higgins, Wall, & Miller, 2005; Tang & Austin, 2009). Learning in technology-supported classrooms also has great potential for improving learning skills, enriching their contents, and enhancing knowledge development (Solhaug, 2009; Wheeler, Waite, & Bromfield, 2002). Likewise, classroom practitioners can effectively employ technologies to increasing students' motivation in learning and promoting collaborative learning (Hall & Higgins, 2005; Schmid, 2008; Slay, Sieborger, & Hodgkinson-Williams, 2008).

While technologies have introduced a revolutionary classroom practice, it remains questionable that their applications achieve equal degrees of pedagogical benefits in language teaching and learning. Salaberry (2001) maintained that pedagogical effectiveness of different technologies must be concerned from four aspects: the correlation between technological sophistication and pedagogical effectiveness, the exploitation of new technologies for pedagogical purposes, the integration of technologies into the curriculum, and the efficiency of using human and material resources. Thus, the purpose of this study was to investigate the pedagogical effectiveness of different instructional approaches of technology and collaboration on English vocabulary learning and retention; it also conducted sequential analyses of students' learning behavior in the computer-supported collaborative learning group to verify their performances. The research questions are: (1) Are there any differences in English vocabulary learning effects and retention among different instructional approaches (collaborative learning in the technology-supported classroom, collaborative learning in a normal classroom, and individual learning)? And, (2) what are the learning behavior patterns that promote English vocabulary learning and retention of the participants in the technology-supported classroom?

LITERATURE REVIEW

Computers and collaboration

Collaborative learning has been applied in education since 1980s for such positive effects as enhancing motivation and critical thinking skills as well as improving academic performance and long-term retention (Brown, 2008; Dillenbourg, Baker, Blaye, & O'Malley, 1996). During the collaborative learning process where social interdependence and interaction take place (Salomon & Globerson, 1989), interpersonal skills, positive attitudes towards group work, and social relationships are also developed. Many maintain that collaborative learning theories are deeply influenced by both Piagetian and Vygotskian approaches, which provide the fundamental premise to account for how learning occurs and how social interaction influences cognitive development. Differences between the two, however, are pointed out. Forman (1987) explained that from a Piagetian perspective, both cognitive and social processes derive from individual process through perspective-taking; the intellectual and social coordination of peers, from a Vygotskian perspective, is exercised through the interaction across individuals. In Brandon and Hollingshead's (1999) words, Piagetian "learning occurs through interaction that produces multiple perspectives that generate cognitive conflict" whereas Vygotskyian "learning occurs when individuals are exposed to a slightly higher level of difficulty" than their present levels (p. 117).
Research on computer-supported collaborative learning (CSCL), coined by O'Malley and Scanlon in 1989 and recognized by Koschmann as an emerging paradigm in 1996 (Lipponen, Hakkarainen, & Paavola, 2004), aims to explore how computers can be used to create an effective learning environment that supports collaboration in small groups (Koschmann, 1996; Stahl, Koschmann, & Suthers, 2006), instead of designing computer programs centered on individual learners (Johnson & Johnson, 2004; Stahl et al., 2006). Although the bulk of previous studies has focused CSCL on the use of network, the integration of technology and collaboration should not be exclusive to networking tasks or online communication at the expense of authentic face-to-face interaction where collaboration can also happen with the aid of computers (Stahl et al., 2006).

Despite of the seeming benefits of combining computers and collaboration, the CSCL issues should be tackled carefully in that both elements are involved with complex sub-issues that deserve further investigation (Stahl et al., 2006). For example, Dillenbourg et al. (1996) indicated that factors, such as group size, group composition, nature of tasks, and communication media, may interact with one another in an intertwined way in which causal links can hardly be established between the learning conditions and effects of collaboration. Furthermore, studies under the label of CSCL involve a great variety in terms of methodological approaches, unambiguous definitions of CSCL, roles of computers, task types, learning goals, group composition, social interaction and instructional environments (Johnson & Johnson, 2004; Lipponen, 2002; Stahl et al., 2006; Strijbos, Kirschner, & Martens, 2004). Therefore, the effectiveness of CSCL should not be taken for granted without considering respective instructional settings where these variables interrelate (Strijbos et al., 2004), for fear of overgeneralizing the integration of technology into classrooms. In the field of language education, the application of technology was found to increase learning motivation and interest, develop positive attitudes toward learning, result in higher-order thinking and better recall, as well as improve language skills (Stepp-Greany, 2002). The advancement of technology has triggered its combination with collaborative learning and application in language classrooms. It is assumed that this combination can bring about benefits from applications of both technology and collaboration in language learning.

Vocabulary learning

The critical importance of vocabulary is undeniable because it not only establishes knowledge structure but also facilitates communication (Coady & Huckin, 1997). Second language (L2) vocabulary acquisition, unlike that in first language (L1), requires more efforts and time. L2 learners, particularly in early phases, need to reach the threshold level of frequent words for their language skills and linguistic knowledge to develop (Nation, 2001). In addition to the vocabulary size, the frequency of vocabulary encounters also has an influential impact on its acquisition (Laufer & Hill, 2000). Although the minimum encounters for effective learning have not been agreed upon, learners need multiple encounters in contexts to acquire words (Nakata, 2006). Repeated exposures have remarkable effects on the increase and retention of vocabulary.

In vocabulary learning, two sets of vocabulary knowledge are involved, receptive and productive (Nation, 2001). While the former refers to words used for comprehension in reading and listening, the latter refers to those for communication in speaking and writing. The relationship between the two sets of knowledge is not static and subject to variation (Melka, 1997). When vocabulary learning is concerned, the receptive set means the ability to understand what a word means in a given context and the productive one means that to use a word in an expression (Laufer, 1991). Because the acquisition of receptive and productive vocabulary involves different degrees of difficulty, the instruction should treat them differently. Receptive knowledge usually precedes and exceeds productive knowledge (Clark, 1993) and production requires a "more complete set of information"

(Melka, 1997). Therefore, it is widely acknowledged that the learning of a word usually progresses from reception to production. Moreover, the quantity of vocabulary should be the main goal if reception and comprehension are stressed. When production is emphasized, vocabulary acquisition should be centered on the quality of learning a small set of vocabulary (Nation, 2001).

Whether or not the receptive and productive knowledge of words can be retrieved successfully is a way to determine the effectiveness of vocabulary learning. To help learners enhance their long-term retention, language practitioners suggest deep processing, rather than shallow processing (Craik & Lockhart, 1972). While shallow processing of phonemic and orthographic components leads to a fragile memory trace susceptible to rapid decay, deep processing at various levels results in a more durable and long-lasting memory trace. Questions of shallow processing may only concern the sound or spelling of words, whereas those of deep processing may connect a word to its meaning in contexts. Deep processing that involved more elaborate mental representation was found to yield better long-term retention.

Similar to the concept of deep processing, the involvement load hypothesis (Hulstijn & Laufer, 2001) maintains that retention of unfamiliar vocabulary is dependent upon the amount of involvement, which consists of need, search and evaluation. Need refers to motivational, non-cognitive dimension whereas search and evaluation refer to cognitive dimensions, conditional upon allocating attention to form-meaning relationships (Schmidt, 1994). Search is concerned with the attempt to find the meaning of an unknown word or a form expressing a concept in L1 by consulting a dictionary or a human source. Evaluation needs a comparison of different words or multiple meanings of a word, and an assessment of the suitability of a word in a certain context. Recognizing these differences is referred to as moderate evaluation, while determining how additional words will combine with a target word in an original sentence or text is referred to as strong evaluation. Based on the hypothesis, some empirical studies have proved that incidental tasks that trigger learners' higher degree of involvement load in terms of their need, search and evaluation of unfamiliar words will lead to effective learning (Kim, 2008; Lu, 2008). Both the involvement load hypothesis and concept of deep processing offer useful pedagogical implications in language learning because they highlight the importance of manipulating task features to activate learners' cognitive processing of vocabulary.

Computer-supported collaborative vocabulary learning

This study established a technology-supported classroom, where L2 learners learn and review English vocabulary with their peers. The review activities are designed in such a way that learners are involved in deep processing of each target word for their receptive and productive knowledge. More details of its implementation are given in the following section.

METHOD

Participants

This study recruited 92 eighth graders from three intact classes in a junior high school in northern Taiwan and 76 participants finished the experiment. Based on the vocabulary size around 800 basic words, their proficiency level is considered beginning. None of the three classes, besides, is significantly superior to the others in their English ability according to a one-way ANOVA of their first monthly test results. The participants have four English classes every week and each meeting lasts 45 minutes. English classes take place in a normal classroom, where one computer with the access to the Internet is connected to an LCD projector. The purpose of English classes is to develop their abilities to use the language. Because of competitive entrance exams and parents' concerns, the focus of English classes is sometimes shifted to exam-driven exercises on form.

Learning environment

In the technology-supported classroom (Figure 1 below), four hardware devices and two software systems were installed.

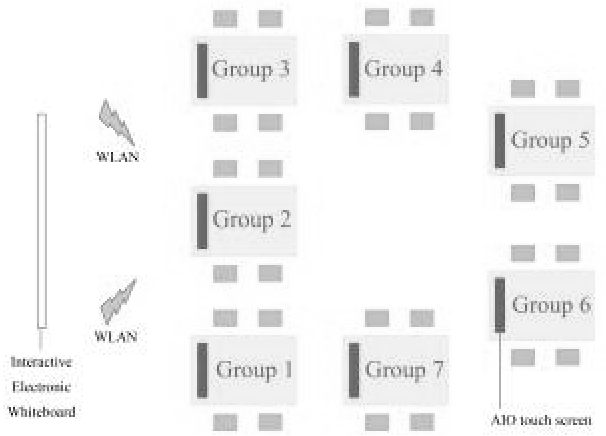

Figure 1. Layout of technology-supported classroom

The hardware devices were an interactive electronic whiteboard, all-in-one touchscreen desktop computers, a material server, and the wireless access point. Interactive electronic whiteboard in the study was a 72-inch touchscreen shown in Figure 2. Connected to a computer and a projector, the whiteboard projected the content of the computer and allowed its users to perform such functions as move, turn, and click to edit and operate with fingers or a touch pen. Not only can the whiteboard present multimedia materials, it can also store operational processes for later access.

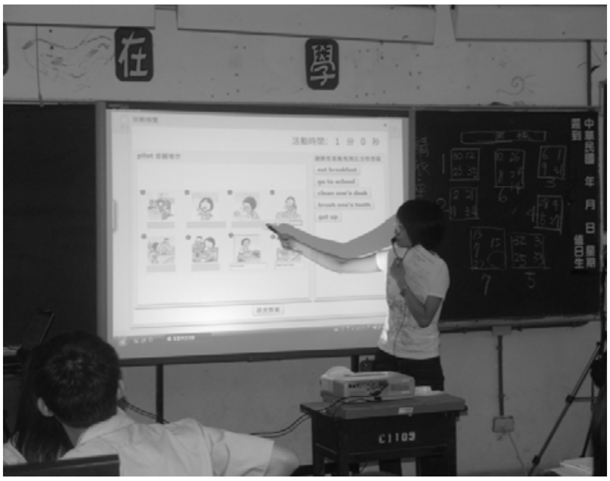

Figure 2. Interactive electronic whiteboard

Figure 3. Students operating touchscreen desktop

A 22-inch all-in-one touchscreen desktop computer was installed for each group (Figure 3). It allowed group members to operate the computer by finger touching; it also served as the platform of collaboration. A material server was used to offer materials to the students and to record students' performances. The teacher could monitor how students respond to questions and decide on necessary follow-up instructions. Finally a wireless access point was set up to promote the interaction between the teacher and the students.

The two software systems were the English Vocabulary Instructional System and the Five Modules of Review Activities of English Vocabulary. The Instructional System was developed with English vocabulary learning strategies (Schmitt, 1997) and long-term memory enhancing strategies in mind (Nation, 2001; Thornbury, 2002). The former learning strategies incorporated those of asking partners for meanings of words, copying and orally repeating words, associating words with pictures, guessing word meanings from the context, enhancing word meaning by using flash cards, using target words in sentences, and translating target words into L1 equivalents (Schmitt, 1997). The latter memory enhancing strategies included repetition, deep processing and pictorial association (Nation, 2001; Thornbury, 2002).

The Five Review Activities consisted of matching, filling in the blanks, translation, unscrambling sentences, and crossword puzzles. The snapshot of each is shown in Figure 4, from left to right, from top to bottom.

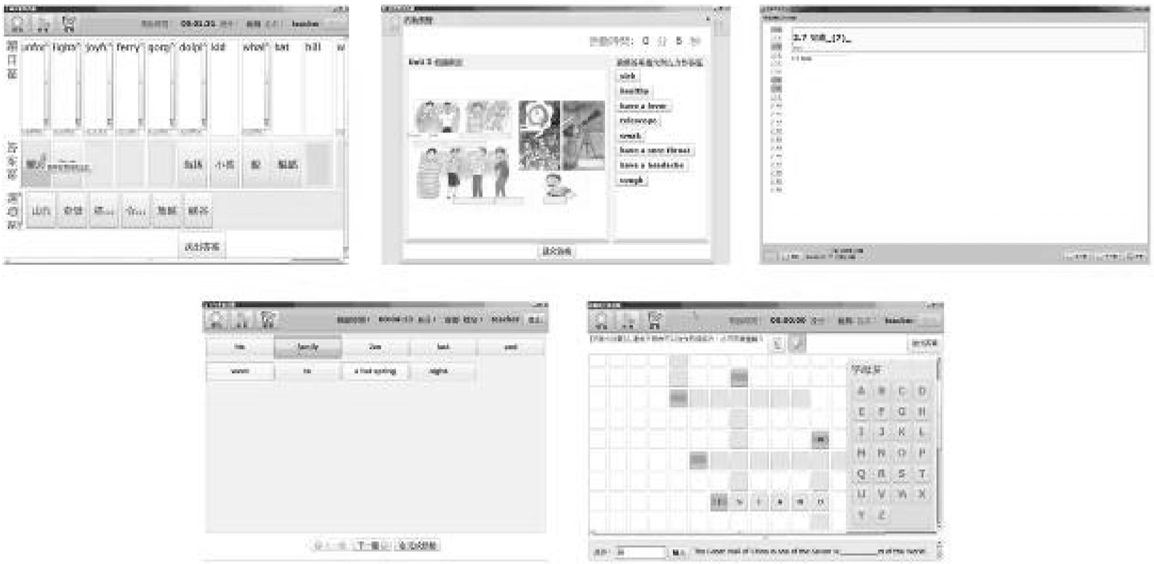

Figure 4. Snapshots of five modules

In the matching exercise, students were required to match English vocabulary items with their Chinese equivalents. Submission was allowed after ten pairs were done. Similarly, in the filling-in-the-blanks activity, students were asked to drag a word icon to match its corresponding picture. After all blanks were filled, students could submit their answers. The translation exercise demands students to type in a target word based on its Chinese equivalent given. Each item was evaluated immediately and scores were displayed. In unscrambling sentences, students needed to shift the order of word icons so that a sentence based on the word icons was grammatically accepted. Students could continue trying until the order was correct. Finally, the word puzzle game required students to type in a target word to fill in the blank of a given sentence.

Materials and instrument

The 30 target words in the study were selected by the participating English teacher and the other two veteran English teachers. The target words were not chosen from the textbook to ensure that the participants had no previous encounters. In each instructional session 10 target words were taught and practiced. The participants received the same vocabulary instructions from the same English teacher in a normal classroom. The only instrument for the study was an achievement test of English vocabulary. The test consisted of 30 recognition questions, each of which asked the participants to choose the correct Chinese word equivalent matching its English counterpart out of three options. Each question weighs one point; thus, the highest point of the test is 30, the lowest 0. The achievement test was administered on papers to each student apiece. The immediate posttest and delayed posttest contain identical items but in different orders.

Procedures and data analysis

The study adopted a non-equivalent control group quasi-experimental research design. The three classes of the same English teacher were randomly assigned to computer-supported collaboration group (experimental group A), computer-free collaboration group (experimental group B), and computer-free non-collaboration group (control group). The experimental group A, in seven groups, was asked to learn the target English vocabulary collaboratively in the technology-supported classroom. When doing the exercises they were allowed to look up digital references. In the experimental group B, the students in a normal classroom were divided into seven groups but were asked to solve the same questions on worksheets. They were allowed to consult dictionaries and class notes when necessary. In the control group, each student was given worksheets of the vocabulary exercises; dictionary and note consultation were allowed.

The study took place immediately after the school's first monthly exam, fall 2009; all participants' scores of their English monthly test were used as the pretest scores. Prior to the treatment, the experimental group A received a 30-minute pre-activity instruction to familiarize themselves with the all-in-one computers. The treatment consisted of three review activities of 10 target words in three class meetings, 30 minutes for each and 90 minutes in total. After each instructional session, the three groups received an immediate posttest. Thirty days after the experiment, a delayed posttest of 30 vocabulary items was administered without prior notice. Three sets of scores were collected: the results of the monthly test as the pretest scores and those of the vocabulary test as the immediate posttest and the delayed posttest. To determine the differences in learning effects and retention, one-way analyses of covariance (ANCOVAs) were used; and, the participants' behavior patterns in the technology-supported classroom were videotaped, coded and categorized.

RESULTS

Learning effects and retention

The pretest scores were those of the English monthly test. A one-way ANOVA was conducted and the results showed no significance among the three groups ($F(2,73)=1.235$, $p>.05$). The descriptive statistics of the two posttests (Table 1) showed that the review vocabulary activities helped our participants learn and acquire the target vocabulary.

Table 1. Descriptive statistics of two posttests

Group	*N*	Immediate Posttest		Delayed Posttest	
		M	*SD*	*M*	*SD*
Experimental Group A	21	26.67	4.44	22.33	6.10
Experimental Group B	27	25.48	5.03	19.19	7.10
Control group	28	27.75	4.35	20.07	7.15

In Table 1, more than 80% of the vocabulary items were learned right after the activities and about 70% were retained 30 days after the treatment. The control group came up with the highest means in the immediate posttest while the experimental group A scored the highest in the delayed posttest.

Based on the results of the pretest and those of the immediate posttest, a test of the equality of variance for the three groups was conducted; and, the homogeneity of with-in regression coefficients was not significant ($F(2,70)=0.382$, $p>.05$). For the learning effects, one-way ANCOVAs were then used to determine whether the differences among the three instructional groups were significant, in which the instructional approaches served as the independent variable, the immediate posttest scores the dependent variable, and the pretest the covariate with the alpha level set at .05. The results from ANCOVA indicated that there is no significant difference among the three instructional approaches ($F(2,72)=2.253$, $p>.05$).

The other test of the equality of variance for the three groups, based on the scores of the immediate posttest and those of the delayed posttest, was performed; and, the results of the homogeneity of with-in regression coefficients did not reach a significant level ($F(2,70)=.045$, $p>.05$). One-way ANCOVAs were then used to determine whether differences in vocabulary learning retention among the three instructional approaches existed, where the instructional approaches served as the independent variable, the delayed posttest scores the dependent variable, and the immediate posttest scores the covariate with the alpha level set at .05. The results from ANCOVA indicated no significance among the three instructional approaches, either ($F(2,72)=1.964$, $p>.05$).

The examination of the differences between the two posttests followed. Differences between the two posttests showed that the control group had the sharpest drop (7.68) and the experimental group A the slowest (4.34). This suggests an analysis in the retention rates, the percentage of the scores of the delayed posttest divided by those of the immediate posttest. The experimental group A had the highest retention rate ($M=86.37$, $SD=16.18$), followed by the experimental group B ($M=74.59$, $SD=23.90$), and the control group the least ($M=71.63$, $SD=24.22$). Three *t*-tests were conducted. While the differences between the two experimental groups ($t=1.938$, $p=.059$) and those between the two computer-free groups ($t=0.455$, $p=.651$) were not significant, the differences between the experimental group A and the control group ($t=2.411$, $p=.020^*$) were statistically significant. The participants, learning collaboratively before touchscreen desktops, outscored the other two groups in the delayed posttest and recalled most.

Learning behavior patterns

To answer the second research question of learning behavior patterns, the participants' learning in the technology-supported classroom were videotaped. Their actions were coded, categorized, and analyzed.

Six types of actions were first categorized. They were reading information on the screen (R), consulting references for meanings (C), discussing with group members (D), determining answers (A), touching the screen or using the keyboard (T), and doing something irrelevant to learning (O). Except for the first and the last types, the other four were correspondent with some long-term memory enhancing strategies mentioned earlier (Nation, 2001; Thornbury, 2002). For example, when discussing with group members (D), our participants employed learning strategies of resorting to a group member. Even though the participants' determining answers (A) may be demonstrated by speaking out the answers in the group, strategies of deep processing and using words in context were involved. Touching-and-moving words on the screen or typing in words (T) involved strategies of using words and retrieving lexical information learned before.

After the coding of 5,304 actions, some sequential patterns were immediately noticed (Bakeman, & Gottman, 1997; Sung, Chang, Lee, & Yu, 2008). A typical sequential pattern observed in the group leaders' collaboration in solving crossword puzzles was that they read the questions first to their group members (R) and discussed to clarify what the questions meant with their group members (D); after the clarification, they decided on answers (A) and typed in answers (T). To record and tabulate sequences of actions in Frequency Transition Table (Table 2), we began with action codes in the rows, "starting action", and found their following action codes in the columns, "subsequent action." Two raters identified 63 and 38 patterns, respectively, and the inter-rater reliability reached a substantial level (Kappa=.62).

Table 2. Frequency transition table

to / from	R	C	D	A	T	O	Total
R	9	45	134	19	87	8	302
C	14	81	293	134	103	14	639
D	137	242	269	458	565	47	1,718
A	20	96	219	25	528	5	893
T	117	163	743	257	343	14	1,637
O	4	13	60	0	11	27	115
Total	301	640	1,718	893	1,637	115	5,304

Most sequential patterns (92%) fell in the middle cells, from C, D, A and T (starting actions) to C, D, A and T (subsequent actions). To test whether the frequency of the patterns was statistically significant, we conducted a sequential analysis based upon the results of Table 2. The strength of each sequence was listed in Table 3. A sequence of actions was considered significantly different when its *Z* value was greater than 1.96. A behavioral-transfer figure (Figure 5) was drawn based on the *Z* values.

Table 3. Adjusted residuals table (*Z*-Scores)

to / from	R	C	D	A	T	O
R	-2.08	1.50	3.88*	-4.74	-0.68	-0.60
C	-4.20	0.50	6.80*	2.90*	-7.63	0.04
D	5.92*	3.56*	-18.02	14.68*	2.23*	2.36*
A	-5.18	-1.36	-4.97	-12.29	18.28*	-3.92
T	3.62*	-3.55	13.36*	-1.62	-10.44	-5.22
O	-1.01	-0.24	3.81*	-4.50	-4.20	15.86*

*p<.05

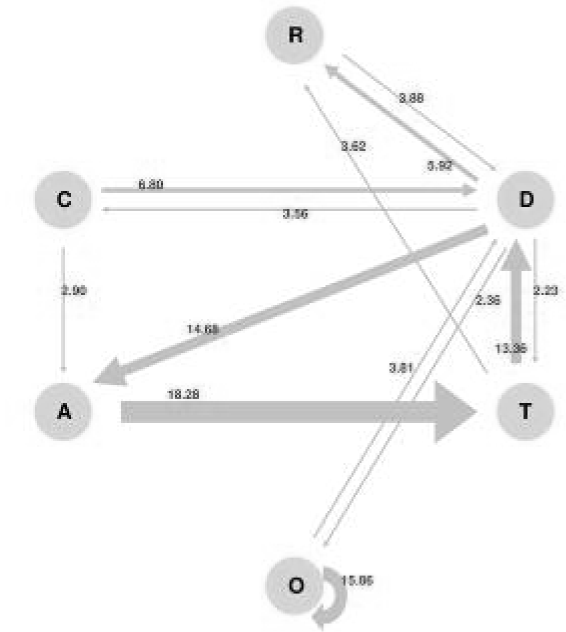

Figure 5. Behavioral transfer diagram

From the *Z*-scores shown above, our participants, learning collaboratively in the technology-supported classroom, mostly performed a sequence of determining answers and entering answers (A to T, 18.28), involved in irrelevant trivia (O to O, 15.86), and elicited answers from group members (D to A, 14.68 and D to T, 13.36). Because of the nature of the learning, their actions centered on discussing with their group members to determine answers (D to A), to enter answers (D to T), and to clarify their comprehension (D to R, 5.92) and their answers (D to C, 3.56).

When analyzing data, we found that our learners' behavior patterns could be further divided. For instance, some participants, after consulting the dictionary (C), would make up their minds (A) and typed in the answers (T); however, there were others, after consulting the dictionary (C), would confirm what they read with their group members (D) before they came up with an answer (A). The class instructor later informed us that the differences observed in comprehending dictionary information could lie in the proficiency levels. After overall analyses individual differences were further noticed and the analyses were conducted in terms of higher proficient learners (top 30% in the pretest) and less proficient learners (bottom 30% in the pretest). Their frequency transition is shown in Table 4.

Table 4. Frequency transition table for higher and less proficient learners

to	R		C		D		A		T		O		Total	
from	H	L	H	L	H	L	H	L	H	L	H	L	H	L
R	2	5	12	22	53	50	5	6	28	32	0	8	100	123
C	1	10	20	53	82	144	67	38	34	36	2	12	206	293
D	51	59	68	123	75	146	245	124	192	229	11	29	642	710
A	11	6	45	32	115	64	12	12	273	113	4	1	460	228
T	34	38	61	50	299	272	131	48	112	124	4	7	641	539
O	0	4	0	13	18	34	0	0	3	6	8	12	29	69
Total	99	122	206	293	642	710	460	228	642	540	29	69	2,078	1,962

Note: H=Higher Proficient Learners; L=Less Proficient Learners

The most common patterns in the middle cells were observed, too. Over 90% fell in these categories, 93.84% for higher proficient learners and 90.27% for less proficient learners. Sequential analyses based on the frequencies were conducted to determine the strengths (Table 5). A sequence of actions was considered significantly different when its *Z* value was greater than 1.96; based on the *Z* values, behavioral-transfer figures for the two groups (Figures 6 and 7) were drawn.

Table 5. Adjusted residuals table (*Z*-Scores) for higher and less proficient learners

to	R		C		D		A		T		O	
from	H	L	H	L	H	L	H	L	H	L	H	L
R	-1.33	-1.02	0.7	0.9	4.18*	0.88	-3.83	-2.34	-0.55	-0.34	-1.24	1.88
C	-3.12	-2.26	-0.1	1.64	2.55*	4.33*	3.52*	0.8	-4.12	-5.84	-0.57	0.62
D	5.34*	3.50*	0.79	2.58*	-12.67	-10.85	12.49*	7.16*	-0.65	3.77*	0.99	1.26
A	-2.99	-2.46	-0.11	-0.4	-2.92	-2.31	-11.43	-3.19	14.10*	7.18*	-1.23	-2.8
T	0.91	1.07	-0.46	-4.69	10.37*	7.60*	-1.32	-2.55	-8.84	-2.76	-2.39	-3.79
O	-1.19	-0.15	-1.72	0.87	3.06*	1.87*	-2.57	-2.93	-2.02	-3.09	12.11*	6.37*

Note: H=Higher Proficient Learners; L=Less Proficient Learners; *p<.05

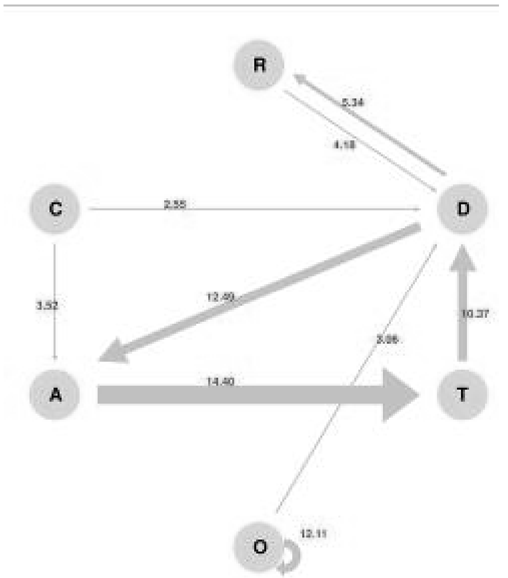

Figure 6. Behavioral transfer diagram: Higher proficient learners

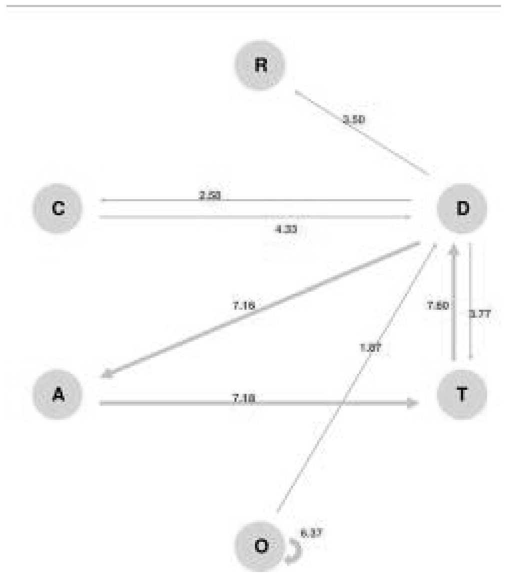

Figure 7. Behavioral transfer diagram: Less proficient learners

Similar behavior patterns between the two groups are correspondent to those of the class discussed earlier. Centering around group discussion, our participants' patterns in both higher and less levels included determining answers and entering answers (A to T, 14.10 & 7.18), eliciting answers from group members (D to A, 12.49 & 7.16), socializing (O to O, 12.11 & 6.37), engaging themselves in discussion or confirming their answers after typed in (T to D, 10.37 & 7.60), clarifying their comprehension (D to R, 5.34 & 3.50), resuming discussing (O to D, 3.06 & 1.87), and discussing what they had from the dictionary (C to D, 2.55 & 4.33).

Differences in our participants' linguistic proficiency were shown in their behavior patterns. What distinguished the two groups were that participants with higher proficiency tended to clarify their comprehension after reading the questions on the screen (R to D, 4.18); and, with their better proficiency, they were likely to determine answers after dictionary consultation (C to A, 3.52). For the less proficient participants, after their discussing with group members, they differed from their counterparts by entering answers to questions (D to T, 3.77) or consulting a dictionary to ensure their comprehension (D to C, 2.58).

One sequence of actions that cannot be ignored is our participants' doing something irrelevant (O to O), second place in the whole group and third and fourth in the higher and lower proficient groups, respectively. This attention dispersion was found in those participants when the touchscreen or the keyboard was dominated, when higher proficient ones were answering questions, or when questions were challenging. They would, most likely, chat with someone next to them, such as exchanging campus information, commenting on classmates' trivia, and discussing after-school activities. Their excluding themselves from the learning activities served as a temporary escape and relief.

DISCUSSIONS AND CONCLUSIONS

The learning effects of collaborative learning in the technology-supported classroom were competitive with those of other two groups. Not only did learning collaboratively in the technology-supported classroom help our participants learn the target words, it also helped them retain the target words. The benefits of vocabulary retention or long-term memory confirmed the findings in previous studies (Brown, 2008; Dillenbourg et al., 1996). The feature, different from other studies, was the touchscreen technology that allowed every group member to participate in the English vocabulary review activities. Surrounding their touchscreen desktops, group members were able to clarify and confirm their comprehension and decisions with each other. Reaching a consensus among group members and later receiving positive feedback from the learning systems facilitated their learning and acquisition.

Explanations for the differences among the instructional approaches, however, were necessary. The participants learning individually showed better vocabulary gain than those in the collaborative groups in the immediate posttest. Because vocabulary is individual-inclined learning, it is reasonable that the control group showed a better learning effect when offered individual-inclined exercises and assessed accordingly. For those in collaborative groups, they may be faced with the problem of attention dispersion. As pointed out, team members tend to exert unequal mental effort on given tasks (Salomon & Globerson, 1989). One of the reasons can be their different perceptions of roles, leading to debilitating effects derived from social loafing, free-riding (Johnson & Johnson, 2000), or differential status (O’Donnell & O’Kelly, 1994). Less proficient learners hid themselves once higher proficient ones took over, especially when tasks were disjunctive and group performance depended on how well the most proficient members did. They abandoned the chances to learn and avoided the responsibility. Being deprived of chances to operate the computer, they acted passively. The fact that passive learners hardly identified themselves with their roles accounted for their lack of devotion. Nevertheless, the insignificant difference of the vocabulary scores between the three groups indicates that those learning collaboratively with computers were not outperformed in vocabulary tests. The treatment of computers and collaboration does not debilitate vocabulary acquisition, even with individual-inclined exercises and assessment. Moreover, learning collaboratively helped learners remember longer and forget less than those learning individually (Kolich, 1991), confirming studies on both collaborative learning (e.g., Johnson & Johnson, 1989) and the use of technology (Stepp-Greany, 2002).

Behavior patterns emerged in this technology-enhanced collaborative vocabulary learning were supportive for Piagetian and Vygotskyian claims. That is, our participants’ deep-processing English vocabulary was in agreement with either perspective-taking or interaction view of learning (Brandon & Hollingshead, 1999; Forman, 1987). No matter what their proficiency levels are, our participants in the technology-supported classroom would reach a consensus before taking a next move. Such behavior patterns were demonstrated by their toggling between group members and various sources, including texts on the screen, dictionary on the desktop, and answers typed in. Group consensus dominated their learning. Our participants’ exchanges of opinions were highlighted in those initiated by less proficient participants. Because of their inferior knowledge about the English vocabulary, the uncertainty about their comprehension of information on the dictionary and about their answers always led them to reconfirm with group members. The interactions between higher and less proficient participants helped both groups construct and reinforce the target knowledge structure of English vocabulary. Their collaboration before touchscreen desktops exemplifies small group collaboration via computer technology (Koschmann, 1996; Stahl et al., 2006), whose learning effects resulted from perspective-taking and intellectual and social coordination (Forman, 1987).

Two points of pedagogical implications can be drawn. First, because of dissatisfaction with appointed grouping, students sometimes should be allowed to form homogeneous groups with members of similar achievement levels or characters. Self-selection may reinforce students’ stereotyping and have the effect of polarizing groups (Ingleton, Doube, Rogers, & Noble, 2000). Once they are familiar with group works, they should be aware of positive interdependence (Johnson, Johnson, & Smith, 1998), understanding that the success of the whole group depends on each member’s participation and contribution. Second, teaching students their responsibility for each role in a group is essential. Although most students have a positive perception towards collaborative learning, they often lack the ability to collaborate, their passiveness to deal with communicative problems and uneven participation. A pre-instruction raising students’ awareness of collaborative learning and individual roles periodically may, therefore, help the groups function effectively.

The significance of findings in the present study is partly restricted by limitations of the number of participants, grouping and research design, therefore, suggestions for future research. First, a larger number of participants are suggested to be recruited lest unpredictable student absence during the data collection process should influence the validity of the results. Second, an ideal number of group members in such a learning context should be under three for fear that at least one or two group members are easily left out or marginalized in a group of 4 to 5 peers. Next, there should be one group for participants to learn individually with computers, so that the learning effects and process can be compared between four groups, with a 2x2 design including treatment of computer/no computer and collaboration/no collaboration. As for data collection, a longer period (Scanlon, Issroff, & Murphy, 1999) and an examination of a group product are strongly recommended to generate more active collaborative behaviors. Also, the behavior patterns found in the current study should be examined with other variables, such as gender, age, personality, learning styles, or affective factors that may influence learners' behaviors when learning with peers and technology support. In this way, more effective and fruitful learning activities are likely to be arranged and designed, not only to promote collaboration but facilitate language learning.

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