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Effects of the Team Competition-Based Ubiquitous Gaming Approach on Students' Interactive Patterns, Collective Efficacy and Awareness of Collaboration and Communication

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ABSTRACT

Previous research has illustrated the importance of acquiring knowledge from authentic contexts; however, without full engagement, students' learning performance might not be as good as expected. In this study, a Team Competition-based Ubiquitous Gaming approach was proposed for improving students' learning effectiveness in authentic learning activities. An experiment on a natural science course was carried out in an elementary school to evaluate the effects of the approach on students' awareness of collaboration, communication and collective efficacy. Moreover, the students' learning behavioral patterns were explored by analyzing their interactive logs in the discussion forum. The experimental results indicated that, in addition to learning achievements, the proposed approach significantly enhanced the students' collective efficacy as well as their awareness of collaboration and communication; moreover, the students who learned with the proposed approach showed more effective behavioral patterns than those who learned with conventional team-based ubiquitous learning.

Keywords

Competition game, Team-based learning, Mobile learning, Ubiquitous learning, Collective efficacy

Introduction

In the past decade, the potential and effectiveness of using handheld devices with emerging facilities such as wireless communication and sensing technologies to support students' learning in authentic contexts has been reported by researchers (Chiang, Yang, & Hwang, 2014; Ozdamli & Uzunboylu, 2015). Via these technologies, students can obtain instant assistance or prompts and access digital materials when learning in related real-world contexts. Such a learning approach has been called context-aware ubiquitous learning (Chen, Chang, & Wang, 2008; Hwang, Tsai, & Yang, 2008). Although the importance of situating students in authentic contexts with support from the learning system has been emphasized, researchers have stated the challenges of learning in such complex learning scenarios consisting of real-world and digital-world contexts and learning resources (Chu, 2014; Kearney, Burden, & Rai, 2015). One of the challenges is the difficulty of having students pay full attention to the ubiquitous learning (u-learning) tasks since there could be many messages or interruptions from the environment they are situated in (Chen, Hwang, & Tsai, 2014). Another challenge is to help students deal with frustrations during the learning process. Thus, it is important to develop a u-learning approach that can encourage students to fully engage in the learning tasks and help them deal with the problems encountered during the learning process (Hsu & Hwang, 2014).

Among various learning support approaches, collaborative learning is considered an effective strategy for assisting students' learning in real-world environments. A well-designed collaborative learning activity can contribute to students' learning effectiveness and encourage them to become active problem solvers (de Laat & Lally, 2003); moreover, collaborative learning activities create more opportunities for individuals to share information, negotiate with peers and make decisions (Curtis & Lawson, 2001). Nevertheless, simply situating students in team-based learning tasks does not necessarily achieve collaboration effects (Gelmini-Hornsby, Ainsworth, & O'Malley, 2011). Researchers have indicated that it is crucial to consider the quality of students' social interactions as well as their engagement when developing collaborative learning activities (Khosa & Volet, 2014; Marcos-García, Martínez-Monés, & Dimitriadis, 2015).

Digital game-based learning (DGBL) is an effective educational approach which is comprised of some enjoyable elements for engaging students in challenging activities (Prensky, 2007). Scholars have pointed out that DGBL, which is regarded as a kind of potential learning approach for promoting students' learning interest and motivation, may provide opportunities for enhancing students' social interactions and engagement in collaborative learning (Ardito, Lanzilotti, Costabile, & Desolda, 2013; Brom et al., 2014; Sung & Hwang, 2013).

The awareness of communication, collaboration and collective efficacy are very important to students since it is the basis of fostering communication and collaboration abilities. Therefore, in this study, a team competition-based ubiquitous gaming approach (TCUG) is proposed to engage students in active learning behaviors and collective effective efficacy, as well as improving their awareness of collaboration and communication.

Literature review

Computer-Supported Collaborative Learning

Collaborative learning, a form of interaction among students, refers to the methodologies designed to engage students in collaboratively solving problems (Eryilmaz et al., 2013; Lai & Hwang, 2014; So & Brush, 2008). Collaborative learning, if appropriately conducted, can not only contribute to students' knowledge sharing and transfer (Noroozi, Teasley, Biemans, Weinberger, & Mulder, 2013), but can also promote their higher order abilities (Chen, Wang, & Lin, 2015). That is, collaborative learning could benefit students by promoting their learning outcomes, collaboration and communication ability (Reeves, Herrington, & Oliver, 2004).

One important factor of collaboration is the discussion that occurs during task engagement (Curtis & Lawson, 2001), which facilitates the sharing of information, negotiation with peers, and decision making (de Laat & Lally, 2003). Gelmini-Hornsby, Ainsworth and O'Malley (2011) described that students can benefit from collaboration when they engage in an effective discussion. Proper instructional methods engage students in socially interacting with peers for questioning as well as elicitation (Remesal & Colomina, 2013; Wang & Hwang, 2012).

One problem of collaborative learning is that students' active interactions with team members are generally rather poor (Crook, 1998). Moreover, lack of engagement in collaborative tasks could result in freeriding or social loafing, that is, the phenomenon of reducing individual striving when working collectively compared with when individually acting on the same learning activity (Gu, Shao, Guo, & Lim, 2015; Triantafyllakos, Palaigeorgiou, & Tsoukalas, 2011).

Although Computer-Supported Collaborative Learning (CSCL) systems seem to be promising in terms of facilitating peer interactions, the result of a CSCL activity could be disappointing without a careful learning design (Gelmini-Hornsby, Ainsworth, & O'Malley, 2011; Slof, Erkens, Kirschner, Janssen, & Phielix, 2010). For example, Wang (2010) provided students with an online shared workspace for collaboration, and asserted that only about half of the groups actively shared resources and negotiated ideas via the workspaces. Therefore, several scholars have indicated the necessity of incorporating effective learning strategies or tools into CSCL activities.

Digital game-based learning

Digital game-based learning (DGBL) refers to those learning activities which integrate computer games into a learning environment (Akcaoglu, 2014; Hwang, Chiu, & Chen, 2015; Prensky, 2007). It has the potential advantages of affording students interactive learning opportunities for stimulating their collaboration (Sung & Hwang, 2013) by situating them in a scenario-based task so as to encourage their active learning and motivate their engagement and satisfaction (Hwang & Chang, 2015; Yang & Chang, 2013). For example, Yang (2015) asserted that digital games provide plentiful opportunities for students' collaboration and sharing of experiences via linking learning with authentic duties, while Li and Tsai (2013) described that digital games can stimulate collaboration due to their characteristics such as instant feedback, clear goals and rules.

In recent years, several studies have taken advantage of digital games in educational environments with the aim of improving students' learning effectiveness. For example, Hwang, Wu and Chen (2012) developed a competitive online board game to promote not only students' learning motivation but also their learning achievement. Ardito, Lanzilotti, Costabile and Desolda (2013) integrated educational games with the discovery learning strategy to help consolidate knowledge stimulating students' collaboration.

Although previous research has described the potential of DGBL for promoting students' learning motivation and fostering their collaborative learning skills (e.g., Sung & Hwang, 2013), there have been few studies on the effects of integrating DGBL and CSCL in the context-aware ubiquitous learning environment. Some previous studies have reported the behavioral analysis results of in-field learning (e.g., Chiang, Yang, & Hwang, 2014);

however, to the best of our knowledge, none of them have investigated students' learning behaviors in collaborative game-based in-field learning, and neither have they evaluated students' perceptions of collaboration and communication. Thus, in this study, a TCUG approach is proposed to enhance elementary school students' collective efficacy as well as their awareness of collaboration and communication, which are likely to affect their corresponding competences in the future, as well as their learning behaviors and performance on field trips.

Research questions

An experiment was conducted to evaluate the effects of the TCUG approach via answering the following research questions.

- Do the students using the TCUG approach display better awareness of collaboration than those using conventional collaborative u-learning?
- Do the students using the TCUG approach display better awareness of communication than those using conventional collaborative u-learning?
- Do the students using the TCUG approach have higher collective efficacy than those who learn with conventional collaborative u-learning?
- Do the students using the TCUG approach show better learning achievement than those learning with conventional u-learning?
- What are the differences between the interactive patterns of the students using the TCUG approach and those using conventional collaborative u-learning?

Context-aware collaborative learning system with a team competition-based gaming approach

Based on the TCUG approach, a team competition-based ubiquitous gaming system has been developed utilizing Visual Studio C# and Android Studio. QR codes are used to guide students to observe specific ecological subjects or phenomena in the field. Each student is provided with a tablet computer to interact with the real-world environment, while a wireless network is provided to not only facilitate their communication with their peers via an online forum but also to enable communication between the tablet computers and the server.

The learning materials of "biology and environmental science" are integrated into gaming scenarios which guide students to explore and observe in a real-world environment on an elementary school campus. The gaming story is related to a southern island country, called "Biodiversity Island." The king of the country, whose name is Formosa, has magic power, so the island is not only full of life and vitality but is also a diverse biological environment. However, the shelters are disappearing due to the excessive use of energy, and the country has been in a state of disarray. A witch, Katrina, takes advantage of the disarray and smuggles in a number of invasive species in order to cause serious destruction to the ecological balance. Therefore, the king dispatches some brave residents, the role students take, to find the reasons for the environmental changes in the ecological systems and to propose solutions to the problems. Students must complete seven tasks in order to recover the king's magic power and restore the vitality of "Biodiversity Island."

A total of 7 gaming tasks were designed for this game, namely "Alien Invasion," "Dark Forces," "Hostile Water," "Dark Breakages," "Airspace Battle," "Territory Battle" and "Honor Battle." Each time the player is allowed to select one of the gaming tasks, except for the last one called "Honor Battle." After the team chooses a gaming task, such as "Alien Invasion," the compelling storyline of the gaming task is shown: "A number of invasive species are smuggled in and hence cause serious destruction to the ecological balance."

Following that, a gaming task consisting of an opening question of the problem-solving activity is displayed: "Lantana camara is considered a kind of invasive species; please explore at least five characteristics of Lantana camara." The team is then guided to find the related learning target in the real-world environment via the map provided by the learning system. When students arrive at the location of the learning target for observation, they are asked to scan a QR-code tag on the target to confirm their physical location, as shown in Figure 1.

Figure 2 shows the main gaming interface, which contains the areas of task description, task prompt, chat room, team ranking, gameplay progression, help seeking, timing and scoring. The members in a team need to collaborate to collect the required data for the gaming tasks in order to get high scores; moreover, a team can only submit an answer if all of the team members agree with the answer. During the gaming activity, the students can discuss face to face or via an online chat room, which enables team members to discuss and share their findings instantly. In addition, to remind the students of the competitive status among the teams, the current top-five gaming scores of all teams are displayed on the gaming interface.

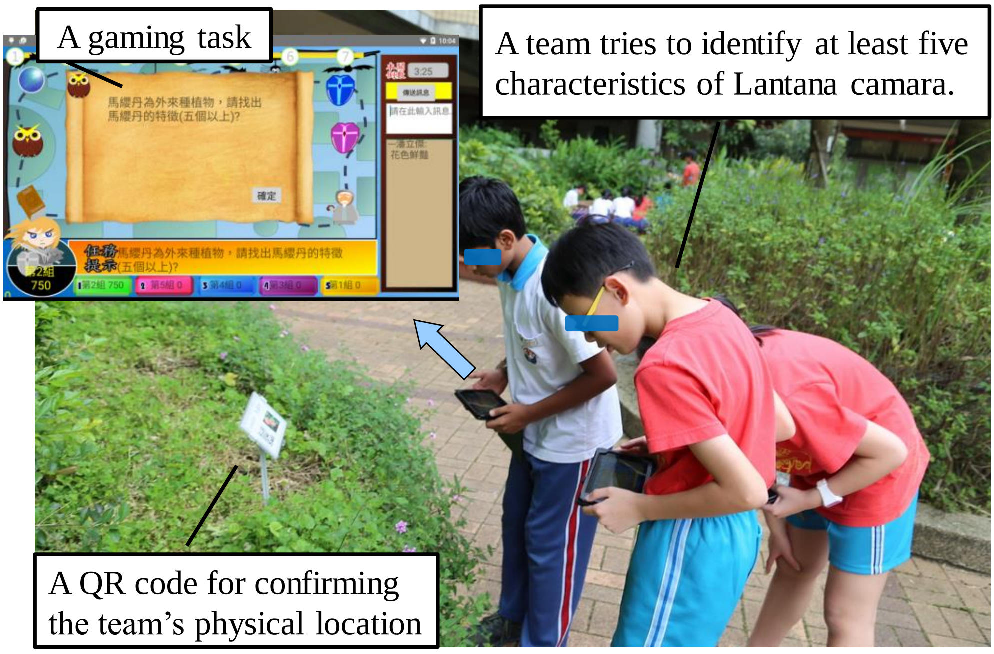

Figure 1. A learning task corresponding to the learning park

The learning team can collaboratively complete the task with the assistance of some tools or NPCs (Non-Player Characters) which are provided by the learning system. For example, a blue shield can provide students with the key characteristic of the creatures and environment, while a red shield prompts them to make comparisons between two kinds of creature or environment with opposite characteristics. A treasury of knowledge provides information about a creature or environment, and a sage can offer some key clues for observing a creature or environment. Moreover, a crystal ball provides the opportunity to find data by connecting to a web search engine.

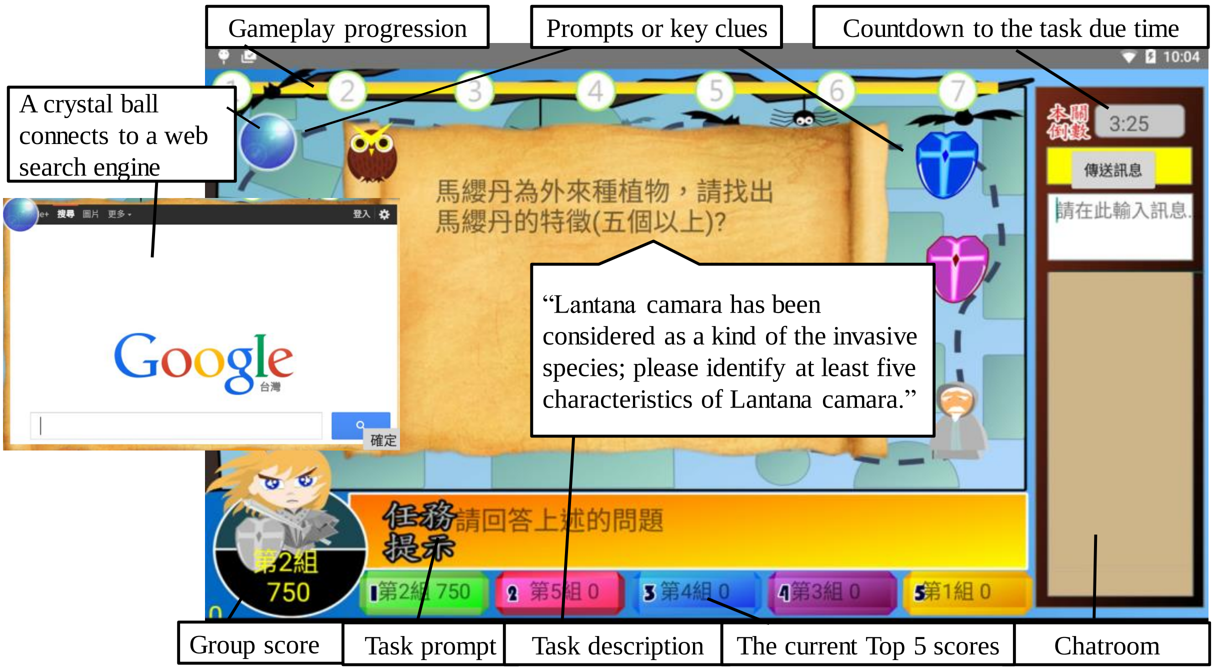

Figure 2. The main Team Competition-based gaming system interface

The solutions to the task must be proposed within five minutes, and two tests have to be completed within a further five-minute period. One is a basic test of recognition and the other is a comparative test related to two creatures or environments. For example, the learning system displays a basic test: “Which one is the key reason for the rapid multiplication of Lantana Camara?” All tests are multiple-choice questions, and the submission is effective after the team members reach a consensus regarding the answer. To facilitate the team members’ consultation with each other, the individual answer is shown on the forum. If a team gives a wrong answer, it is allowed to resubmit the answer. The earlier a team gives the right answer, the more points it gets. After a team successfully completes the task, a compelling storyline about winning this gaming task battle is presented.

After completing the first 6 gaming tasks, the team is allowed to challenge the last one that is the “Honor Battle.” Once a team completes this task related to solar energy and energy efficiency, the vitality of “Biodiversity Island” is restored and the game is completed.

Method

Participants

The participants in this study were four classes of sixth graders (11.5 years old on average) taking a natural science course for four periods a week in an elementary school in northern Taiwan. The four classes consisted of a total of 101 students who were taught by the same teacher who has more than ten years’ science teaching experience in the elementary school. Two classes were assigned to be the experimental group (n = 50) who learned with the team competition-based collaborative ubiquitous learning, while the other two were the control group (n = 51) who learned with the collaborative ubiquitous learning. During the learning activity, the students in both groups were assigned to small learning teams, each of which had 3 or 4 team members with different knowledge levels.

Experimental procedure

The collaborative ubiquitous learning activity about the “biology and environmental science” unit of the elementary school natural science course was conducted to evaluate the effects of the team competition-based gaming approach. The students collaboratively completed the tasks in a real-world learning environment via the guidance of the Team Competition-based Ubiquitous gaming system; moreover, a fantasy story based on the authentic environment and learning topic was displayed to engage the students in completing the learning tasks.

Before the experiment, the students were instructed via a regular eight-period course to learn the fundamental knowledge of biodiversity. Following that, they filled out the pre-questionnaire of collaboration, communication competences and collective efficacy.

Afterwards, the participants started to deal with the collaborative ubiquitous learning tasks. The experimental group used the team competition-based gaming approach. On the other hand, the control group learned with the collaborative ubiquitous learning approach without the gaming mechanism; that is, they were asked to complete the same learning tasks in the same real-world learning environment. In addition, the learning materials and guidance or hints provided to both groups were identical. To engage the students in deep research on the creatures and the learning environment, all teams were subsequently required to complete a report about environmental changes during the activity.

After the learning activity, the students filled out the post-questionnaires of collaboration, communication competences and collective efficacy. Finally, nine students were randomly selected from each group for a one-on-one interview to collect their learning perceptions of and opinions on the learning activity.

Measuring tools

The measuring tools adopted in this study included the questionnaires of collaboration, communication competences, collective efficacy, pre-test, post-test, and interactive content coding scheme.

The questionnaire of students’ awareness of their collaboration was designed based on the study announced by Lai and Hwang (2014). It consists of five items with a five-point Likert rating scale, such as “When I worked with my team members, I think our conversation was good" and "When peers propose their opinions, I will not question their motivation." The Cronbach's alpha value of the questionnaire stated by the original study was 0.85, implying highly acceptable reliability in internal consistency.

The survey of students' awareness of their communication was adopted based on modifying the measurement developed by Lai and Hwang (2014). A total of five items (e.g., "When I talk with someone, I feel comfortable." and "When I talk with peers, I will consider their feelings.") made up the questionnaire with a five-point Likert scale. The Cronbach's alpha coefficient stated by the original study was 0.88, implying highly acceptable reliability of the students' communication questionnaire.

To investigate students' collective efficacy, the survey developed by Wang and Hwang (2012) was adopted, which was based on the questionnaire proposed by Pintrich, Smith, Garcia and McKeachie (1991). This survey consists of eight items with a five-point Likert scale, such as "I am confident that our team can understand the most complicated part of this work through teamwork" and "I am confident that our team can finish this work well." The alpha reliability score described in the original study was 0.92, indicating highly acceptable reliability in internal consistency.

To evaluate students' learning achievement, the pre-test and post-test were designed by two natural science teachers with years of teaching experience. The pre-test, which comprised 20 multiple-choice items, was related to the fundamental knowledge of biodiversity. On the other hand, the post-test, which consisted of 26 multiple-choice items and four short answer questions, was about the course of "creatures and environment." The perfect score of each test was 100.

Regarding the analysis of students' interactive content, this study utilized the Interaction Analysis Model (IAM) coding scheme, developed by Gunawardena, Lowe and Anderson (1997). This scheme, which has been adopted in some of the previous research (Chiang, Yang, & Hwang, 2014; Hou, Chang, & Sung, 2008; Lan, Tsai, Yang, & Hung, 2012) was used to analyze students' cognitive behavior on the forum. IAM divided the discussion content into five levels, as shown in Table 1.

Table 1. The IAM coding scheme for analyzing interactive content

Code	Level	Definition
L0	Content irrelevant to the learning topic	Content that is completely unrelated to what is being discussed or considered.
L1	Sharing or comparing information	Simply explaining the observation or opinion; Agreeing with a peer's idea.
L2	Exploration of inconsistency among team members	Illustrating the dissonance between different ideas or opinions; Questioning about the topic and proposing one's opinions.
L3	Negotiation or construction of knowledge	Abstracting and illustrating the issues or opinion on the topic.
L4	Comparison and modification of the proposed synthesis or newly constructed knowledge	Comparing the conclusions of the discussions with existing knowledge; Proposing individual points in contrast with personal experience or references.
L5	Agreement or application of newly constructed meaning	Inducing the discussions; Proposing deeper reflection, new construction or metacognition.

Experimental results

Awareness of collaboration

A one-way ANCOVA was utilized to measure the students' awareness of collaboration competence using individual pre-questionnaire scores as a covariate, ubiquitous learning approaches as an independent variable, and the post-questionnaire score as a dependent variable.

After verifying that the assumption of homogeneity of regression was not violated with $F = 0.09$ ($p > .05$), the post-questionnaire scores were analyzed with ANCOVA. As shown in Table 2, a significant impact of the ubiquitous learning approach was found on the two groups with $F = 6.21$ ($p < .05$, $\eta^2 = 0.060$). Moreover, the adjusted mean values and standard deviation errors of the students' perception scores were 4.12 and 0.10 for the experimental group, compared with 3.78 and 0.10 for the control group. It was confirmed that the awareness of collaboration of the students using the team competition-based gaming approach was significantly higher than that of the students adopting the collaborative ubiquitous learning approach. Furthermore, according to the definition proposed by Cohen (1988), the ANCOVA results of the ubiquitous learning model gave a moderate effect size with $\eta^2 > 0.059$.

Table 2. The ANCOVA results for the students' awareness of collaboration

Group	*N*	Mean	*SD*	Adjusted mean	Std. error	*F*	η^2
Experimental group	50	4.12	0.69	4.12	0.10	6.21*	0.060
Control group	51	3.78	0.86	3.78	0.10		

Note. $^{*}p < .05$.

Awareness of communication

As for the impact of the Team Competition-based Ubiquitous gaming system on the students' awareness of their own communication competence, a one-way ANCOVA was conducted by adopting ubiquitous learning approaches as an independent variable, while the post-questionnaire scores were a dependent variable and the pre-questionnaire scores were a covariate.

In order to judge whether the use of ANCOVA was proper, the homogeneity test was computed first. It was found that the assumption of homogeneity of regression was passed with $F = 0.43$ ($p > .05$). Following that, ANCOVA was performed and a significant difference ($F = 8.73$, $p < .01$, $\eta^2 = 0.082$) was proved between the two groups (as shown in Table 3). The adjusted mean values of the students' awareness of communication ratings for the experimental group and control group were 4.35 (Std. error = 0.12) and 3.86 (Std. error = 0.12), respectively. It was found that the Team Competition-based Ubiquitous gaming system had a significantly positive effect on the students' awareness of their communication competence in the real-world ubiquitous learning activity.

Table 3. The ANCOVA results for the students' awareness of communication

Group	*N*	Mean	*SD*	Adjusted mean	Std. error	*F*	η^2
Experimental group	50	4.36	1.00	4.35	0.12	8.73**	0.082
Control group	51	3.85	0.85	3.86	0.12		

Note. $^{**}p < .01$.

Collective efficacy

The homogeneity of the regression slopes was confirmed with $F = 0.28$ ($p > .05$), and afterwards ANCOVA was performed. The ANCOVA results in Table 4 describe the significant difference between the two groups ($F = 10.36$, $p < .01$, $\eta^2 = 0.096$) with moderate effect size; moreover, the adjusted mean values and standard deviation errors of the students' collective efficacy ratings were 4.24 and 0.08 for the experimental group, and 3.86 and 0.08 for the control group. Accordingly, the collective efficacy of the students using the team competition-based gaming approach was significantly higher than that of the students using collaborative ubiquitous learning. In other words, the Team Competition-based Ubiquitous gaming system can effectively promote students' collective efficacy in a real-world ubiquitous learning environment.

Table 4. The results of the ANCOVA on students' collective efficacy

Group	*N*	Mean	*SD*	Adjusted mean	Std. error	*F*	η^2
Experimental group	50	4.21	0.64	4.24	0.08	10.36**	0.096
Control group	51	3.88	0.77	3.86	0.08		

Note. $^{**}p < .01$.

Learning achievements

To analyze the influence of the TCUG approach on the learning achievement of the students with different pre-test scores, students in each group were divided into two subgroups, namely "high-pre-test" and "low-pre-test," based on their pre-test scores. Furthermore, the one-way ANCOVA was utilized by taking the pre-test scores as a covariate, while the ubiquitous learning approaches were an independent variable and the post-test scores were a dependent variable. The assumptions of homogeneity of regression were assessed for the two levels, and the F values for "high-pre-test students" level and "low-pre-test students" level were 0.06 ($p > .05$) and 0.26 ($p > .05$), respectively. Accordingly, it was reasonable to execute ANCOVAs to evaluate the different pre-test levels of students' learning achievement for the TCUG approach.

As described in Table 5, the significant effects of the ubiquitous learning approaches were found to be $F = 4.18$ ($p < .05$; $\eta^2 = 0.077$) for the high-pre-test students and $F = 11.76$ ($p < .01$; $\eta^2 = 0.207$) for the low-pre-test students, indicating that the post-test scores of these two pre-test levels were significantly different. Moreover, the adjusted means of the high-pre-test level's post-test scores were 87.86 (Std. error = 2.17) for the experimental group and 81.22 (Std. error = 2.21) for the control group, indicating that the TCUG approach can improve high-pre-test students' learning achievement. On the other hand, the low-pre-test students (adjusted mean = 82.54, Std. error = 2.21) who participated with the TCUG approach outperformed those who participated with collaborative ubiquitous learning (adjusted mean = 71.74, Std. error = 2.12) in terms of their learning achievement. According to Cohen's (1988) declaration, the ANCOVA results of the TCUG approach represented a moderate effect size ($\eta^2 > 0.059$) and large effect size ($\eta^2 > 0.138$) for the high-pre-test level and low-pre-test level students, respectively.

Table 5. The results of the ANCOVAs on students' learning achievement

Level	Group	*N*	Mean	*SD*	Adjusted mean	Std. error	*F*	η^2
High-pre-test level	Experimental group	27	86.78	9.15	87.86	2.17	4.18^{*}	0.077
	Control group	26	82.35	12.38	81.22	2.21		
Low-pre-test level	Experimental group	23	79.91	10.11	82.54	2.21	11.76^{**}	0.207
	Control group	25	74.16	14.27	71.74	2.12		

Note. $^{*}p < .05$; $^{**}p < .01$.

Interactive behaviors in the online forum

A total of 585 messages (experimental group 313, control group 272) in the chat room were recorded in the learning portfolio database, all of which were coded based on the IAM scheme. It was found that 94.57% and 95.99% of the peer interactions in the experimental group and control group, respectively, were scored as L1 or L2; that is, most of the students spent much time on lower-level social knowledge construction behaviors. The inter-rater kappa reliability of the IAM coding for the experimental group and the control group was 0.77 and 0.75, respectively. Accordingly, excellent inter-rater reliability ($k > 0.75$) and fair to good reliability ($0.40 < k < 0.75$) were confirmed based on the description given by Fleiss, Levin and Paik (1981).

A lag sequential analysis was utilized to explore the participants' behavioral patterns on the online forum. The adjusted residuals of the experimental group are illustrated in Table 6, and five sequences are confirmed to be statistically significant, including L1→ L1, L2→ L2, L2→ L4, L3→ L3 and L4→ L5.

Table 6. Adjusted residuals of the experimental group for IAM

	L0	L1	L2	L3	L4	L5
L0	0.00	0.00	0.00	0.00	0.00	0.00
L1	0.48	6.57^{*}	-5.89	-1.53	-2.14	-1.14
L2	-0.40	-6.47	6.62^{*}	0.40	2.64^{*}	-0.57
L3	-0.20	-1.38	0.37	2.60^{*}	-0.34	-0.28
L4	-0.10	-0.58	-0.71	-0.34	-0.18	6.98^{*}
L5	0.00	0.00	0.00	0.00	0.00	0.00

Note. $^{*}p < .05$.

Based on the significant sequences, a behavioral transfer diagram of the experimental group during the online forum is schematized in Figure 3. The continuously repeated relationships are shown for social knowledge construction; for example, L1→ L1, L2→ L2 as well as L3→ L3. Continuous actions represented in L1, L2 and L3 indicated that the experimental group preferred completing one gaming task before conducting a further one. For instance, L1 to L1 (sharing or comparing information) described that the participants collaboratively searched for and shared the information about the topics for a while; peers illustrated the dissonance between different ideas or opinions, asking questions about the topic or proposing opinions, represented by the L2 to L2 sequence; moreover, they engaged in abstracting the issues of the topic, described by the L3 to L3 sequence. Moreover, the sequence L2→ L4 implied that individuals may propose their point in contrast to personal experience or references via the exploration of peers' inconsistencies. Following that, the agreement or application of newly constructed meaning may take place according to the L4 to L5 sequence.

The interaction behavioral patterns of the control group were also analyzed. Table 7 illustrates the adjusted residuals with three statistically significant sequences: L1→ L1, L2→ L2 and L0→ L0.

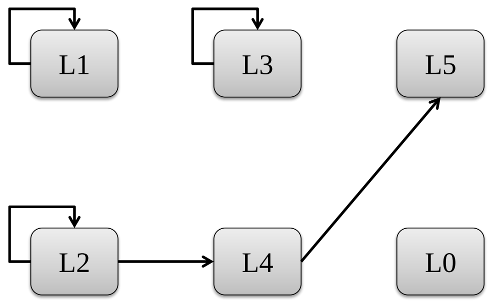

Figure 3. Behavioral transfer diagram of the experimental group for IAM

Table 7. Adjusted residuals of the control group for IAM

	L0	L1	L2	L3	L4	L5
L0	2.96*	-0.01	-0.97	-0.35	0.00	0.00
L1	-0.08	3.42*	-3.34	-0.94	0.00	0.00
L2	-0.94	-3.74	3.94*	1.30	0.00	0.00
L3	-0.32	-0.01	0.28	-0.35	0.00	0.00
L4	0.00	0.00	0.00	0.00	0.00	0.00
L5	0.00	0.00	0.00	0.00	0.00	0.00

Note. $^{*}p < .05$.

A behavior transfer diagram was depicted on the basis of the significant sequences, as shown in Figure 4. The continuously repeated relationships, which are similar to those of the experimental group, were confirmed via L1→ L1 and L2→ L2. However, there was no significant relationship from L3 to L3 (Negotiation or construction of knowledge). Instead, peers may continuously talk about something irrelevant to the learning topic, as revealed by the L0 to L0 sequence.

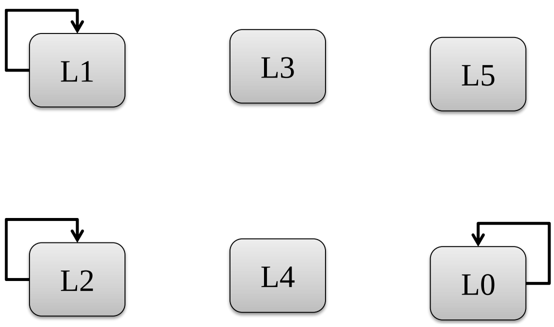

Figure 4. Behavioral transfer diagram of the control group for IAM

Discussion and conclusions

In this study, a team competition-based learning system was developed for assisting students' learning in a real-world environment. An experiment was conducted on a natural science course in an elementary school. The experimental results indicated that, in addition to learning achievements, the TCUG approach significantly improved students' awareness of their collaboration and communication competences as well as their collective efficacy. It was also found that the TCUG approach more significantly benefited the low pre-test students' learning achievement more than that of the high pre-test students, showing the positive effects of integrating the team competition-based gaming approach into ubiquitous learning activities on low-achievement students. Moreover, the students using the TCUG system apparently revealed more higher cognitive level interactive patterns than those who used the conventional u-learning system, such as from L2 "sharing or following information" to L4 "comparing and modifying newly constructed knowledge or proposing new perspectives," and from L4 to L5 "inferring or making reflections based on newly constructed meanings." In addition, the repeated interactive behaviors L3→ L3 (i.e., Negotiation or construction of knowledge) also showed that the students in the experimental groups had better communication and collaboration than the control group. This implies that the TCUG approach can promote the quality of social interaction among peers in the chat room owing to the integration of the learning contexts and the gaming storyline.

Scholars have stated that it is important to effectively promote students' higher cognitive-level interactions via appropriate assistance in a collaborative learning environment (Gelmini-Hornsby, Ainsworth, & O'Malley, 2011). By way of illustration, Strijbos (2011) claimed that participants' engagement may affect the quality of the collaboration. From the behavior patterns of IAM in this study, it was found that the Team Competition-based Ubiquitous gaming system can promote peers' social interaction, which is considered as an important factor in the effects on collaborative learning. This may be the reason why the TCUG system promoted the students' awareness of the collaboration and communication. This is consistent with the finding asserted by Sánchez and Olivares (2011), who inferred that students' awareness of their own collaboration performance might be promoted via a game-based mobile learning environment.

On the other hand, the behavior patterns also illustrate why the students in the TCUG group demonstrated higher collective efficacy than those in the collaborative ubiquitous learning group. Such a finding provides strong evidence to support those collective efficacy studies inferring that the quality of group interactions plays an important role in constructing and promoting collective efficacy in a computer-supported collaborative learning environment (Wang & Hwang, 2012; Wang, Hsu, Lin, & Hwang, 2014). Bandura (2000) indicated that perceived collective efficacy could act as a stimulant to groups' motivational commitment to their missions and performance accomplishments. This could also be a reason why the TCUG approach facilitated the students' collaboration performances as well as their learning achievements. Such a finding also confirms the finding of Wang and Hwang (2012), who indicated that collective efficacy significantly motivated group members' commitment to collaborative tasks while also improving their collaborative performance.

As it is a challenging issue to integrate gaming scenarios into an authentic learning environment in order to enhance students' learning effectiveness (Chen, Liu, & Hwang, 2015; Schmitz, Klemke, & Specht, 2014), the findings of this study provide a good reference for those who intend to develop effective and motivational learning environments for authentic activities. Moreover, the proposed approach could be advantageous to teachers who plan to situate students in collaborative in-field learning. In the meantime, from the learning behavior analysis, it was found that the participants spent much time on lower-level social knowledge construction behaviors in the online forum. Thus, it is worth exploring additional strategies to promote the quality of the peer discussion. For example, we are planning a follow-up study that aims to provide students with visualized knowledge construction tools to promote their behavioral levels for social knowledge construction in the discussion forum.

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