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The evaluation of different gaming modes and feedback types on game-based formative assessment in an online learning environment

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ABSTRACT

This study proposed an online learning system for energy education, modifying the typical rules of tic-tac-toe and incorporating multiple choice tests into the game in order to develop a game-based formative assessment tool for an online learning course. In order to explore how different gaming modes and feedback types in this game-based formative assessment affect knowledge acquisition effectiveness and participation perceptions, a tic-tac-toe quiz game (TRIS-Q) with two gaming modes: single-player online game (SOG) and multi-player online game (MOG), and two feedback types: immediate elaborated feedback (IEF) and no immediate elaborated feedback (no IEF), were developed. A 2(SOG vs. MOG) × 2(IEF vs. no IEF) between-subject experiment was also conducted to investigate the effects on 109 ninth-grade students from four junior high school classes. The research findings indicated that different gaming modes of TRIS-Q did not affect the effectiveness of knowledge acquisition; providing IEF for each question answered in the game facilitated the enhancement of both energy knowledge acquisition and student tic-tac-toe ability when comparing it with the no IEF type. Additionally, the different gaming modes and feedback types did not affect participation perceptions.

1. Introduction

Online courses are acknowledged in the current educational system because they generate numerous merits unavailable in traditional settings (Bell & Federman, 2013; Billings, 2007; Duffy, Lowyck, & Jonassen, 1991). However, many researchers have claimed that the primary problem of online courses is their higher dropout rates (Frankola, 2001; Jun, 2005; Meister, 2002); this is primarily because individualized learning environments can cause students to lose their learning motivation when interaction and timely guidance are lacking. Thus, in order to enhance both interaction and guidance, online synchronous and asynchronous communication tools, such as chat rooms, video conferencing and forums have become common functions in online learning systems (Billings & Rowles, 2001; Reid, Flam, & Tsiouris, 2012). In addition, to prevent online learners from losing learning motivation when reading online learning contents, multimedia materials, including audio, video, animation, or even game-based learning are advocated in designing online courses (Aldrich, 2009; Prensky, 2001).

Furthermore, online formative assessment functions are also required in current online learning systems for self-assessment and self-improvement when learners engage in individualized learning (McKimm, Jollie, & Cantillon, 2003; Vasilyeva, Pechenizkiy, & Paul De Bra, 2008). However, although online formative assessment offers opportunities to repeat tests or practice at convenient times, some studies also found that not all online learners use online formative assessment tools in their online learning (Buchanan, 2000; Henly, 2003). An increasing number of researchers (Costal, Mullan, Kothe, & Butow, 2010; Lin & Lai, 2013) have noted that enhancing the participation rate for using online formative assessment in online learning has become more critical.

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In order to address the above problem, some scholars have proposed employing game-based formative assessments in online learning. For example, Wang (2008) verified that game-based formative assessment can enhance motivation to use online assessments and improve learning effectiveness. However, since traditional online assessments are used individually, current game-based formative assessments in online learning, such as in Wang's research, typically adopt a single-player online game (SOG) strategy. As a result, research related to multi-player online game (MOG) strategies in online formative assessments is sparse, despite the fact that massively multi-player online games (MMOGs) have increasingly become the dominant form of computer games for adolescents.

Therefore, this study attempted to develop an online formative assessment game with MOG strategy for exploring its effectiveness used in an online learning course for energy education. The following section will first discuss how this study adopted the MOG strategy and formative feedbacks suitable for designing this formative assessment game. Subsequently, the research questions and hypotheses of the study will be described.

1.1. MOG strategy suitable for designing formative assessment game

Many people, when playing a game, experience a degree of pleasure, typically becoming so focused that they enter what Csikszentmihalyi (1990) called the state of flow. Thus, gaming is recognized as an activity that can stimulate intrinsic motivation (Garris, Ahlers, & Diskell, 2002; Malone, 1981). Because various educational programs are required to stimulate the intrinsic motivation of learners, games are often applied in education (Randel, Morris, Wetzel, & Whitehall, 1992). With the rapid development of technology, computer games have increasingly replaced traditional games in young people's daily lives, and the online courses are being used in a wide variety of different environments, such as schools and enterprises. Based on the trend for the research toward many positive effects of playing digital games (Connolly, Boyle, MacArthur, Hainey, & Boyle, 2012; Gee, 2003) and the requirement of promoting motivation for online learners, computer games are also applied in online education. Nowadays the well-known terms such as digital game-based learning (DGBL) or serious game have been established for referring to the digital games on educational purposes, and used widely in online learning.

Numerous studies have indicated that DGBL enhances student learning motivation and effectiveness (Clark, Nelson, Sengupta, & D'Angelo, 2009; Vogel et al., 2006; Yang, Chien, & Liu, 2012). As technology and the Internet have developed, multiple studies on DGBL (Barab, Thomas, Dodge, Carteaux, & Tuzun, 2005; Tsai, Yu, & Hsiao, 2012) have used the MOG strategy. However, Tsai et al. concluded that multi-player DGBL was likely to generate over-competitiveness, causing players to overlook learning content, particularly in real-time-based MOG. Whereas the MOGs using real-time strategy involve time limits, others are turn-based MOGs, such as board and card games. Board games require turn-taking, and when one person is playing, other participants must wait. For example, tic-tac-toe is a classic turn-based multi-player game developed in Egypt (Zaslavsky, 1982); two players take turns placing the pieces on a 3×3 table. The first person who makes a row, column, or diagonal line of three pieces is the winner.

Because the rules and the game itself are simple, tic-tac-toe is a commonly played game, and is appropriate for everyone (Crowley & Siegler, 1993). A tic-tac-toe-based game therefore seems to be suitable for use in designing a formative assessment game rather than a real-time-based game, since it requires no player urgency, allowing participants sufficient time to think. Meanwhile, the simple game rules are appropriate for students, and it can be developed as SOG or MOG. For example, Hung's (2011) study combined computerized tic-tac-toe with formative assessment as a single-player formative assessment game. Moreover, many studies have indicated that playing chess is an educational activity because it can increase concentration and enhance problem-solving, memory and mathematics competency (Gobet & Campitelli, 2006). Some researchers (Bönsch, 1987; Kotov, 1971) also indicated that repeatedly playing chess enhances chess-playing ability. Hence, tic-tac-toe was adopted as the game strategy for designing the game-based formative assessments in this study.

1.2. Formative feedback types suitable for designing formative assessment game

Learning assessment can typically be divided into summative and formative assessments. Summative assessment is conducted after the whole learning activity is completed to assess total learning effectiveness regarding specific course materials, and whether the student performed successfully overall (Bloom, Hastings, & Madaus, 1971). Formative assessment was first proposed by Scriven (1967) and later defined by Bloom, Hasting and Madaus, whose definition has been widely used. It is mainly used during the learning process to provide learning feedback and enhance learning performance (Sadler, 1998). Thus, formative assessment is crucial to individualized online learning because the immediate feedback provided by online formative and computer-assisted assessment enables students to immediately self-assess and self-improve. Many studies have also supported that learning motivation and performance are improved in an online learning environment with the engagement of online formative assessment (Gardner, Sheridan, & White, 2002; Henly, 2003; Khan, Davies, & Gupta, 2001).

Feedback in educational situations has always been viewed as a critical factor for improving knowledge and acquiring skills (Shute, 2008). The primary value of online formative assessment is that the mechanism of computer-assisted assessment can provide immediate feedback messages tailored to the learner's assessment results (Dalziel, 2001). Based on the level of information presented in feedback messages, the common formative feedback types can be divided into knowledge of results (KR), knowledge of correct response (KCR) and elaborated feedback (EF) (Dempsey, Driscoll, & Swindell, 1993; Shute, 2008). KR feedback informs students whether their answer is correct or incorrect, but does not offer the correct answer. KCR feedback offers the correct answer, whereas EF may or may not reveal the correct answer, and provides a detailed message that comprises information or clues relevant to the question, guiding learners toward the correct answers. Furthermore, based on feedback timing, feedback can be divided into immediate feedback (IF), which provides instant feedback to learners after completing the assessment or a question, and delayed feedback (DF), which provides feedback messages after a few minutes or longer (Shute, 2008).

Findings regarding IF and DF vary as each has advantages. Certain scholars have proposed that because IF prevents incorrect answers from entering the memory, using IF should lead to superior learning effectiveness compared with DF (Corbett & Anderson, 1989; Dihoff, Brosvic, Epstein, & Cook, 2003). Other scholars have also asserted that IF should be a required strategy for online formative assessment in online learning (Buchanan, 2000; Henly, 2003); however, others have contended that DF enhances learner memory, allowing them to easily memorize correct answers (Kulhavy & Anderson, 1972; Surber & Anderson, 1975). Most studies have indicated that compared with

KR, KCR and EF provide more effective feedback for improving learning effectiveness (Bangert-Drowns, Kulik, Kulik, & Morgan, 1991; Van der Kleij, Timmers, & Eggen, 2011), and that providing only 'correct or incorrect' messages was insufficient; rather, refined messages are required to facilitate learning. However, according to Buchanan (2000) and Wang (2008), learners that answer questions incorrectly in online formative assessments should not be provided with correct answers. The feedback for online formative assessments should provide a relevant reference to guide students, promote their learning and allow them to correct mistakes; EF feedback should not include correct answers.

Because IF and DF demonstrate unique advantages, in designing the game-based formative assessment, this study simultaneously adopted both types of feedback timing; after answering each question, learners were provided with IF, depending on their answers, or learners could check their answering history with DF at any time after completing the assessment. Regarding the level of feedback messages adopted in this study's game-based formative assessment, since withholding the correct answers facilitated learning, KR and EF, but not KCR, were chosen. The KR feedback messages only informed learners whether their answers were correct or incorrect, and did not provide correct answers; however, learners were also provided with EF, which provides relevant information to guide them toward the correct answers. Thus, by blending the four types of feedback (IF, DF, KR and EF) into game-based formative assessment, this study adopted immediate knowledge of results (IKR), delayed knowledge of results (DKR), immediate elaborated feedback (IEF) and delayed elaborated feedback (DEF) as the feedback mechanism for designing the game-based formative assessments.

1.3. Research questions and hypotheses

Based on theoretical basis discussed above, this study incorporated multiple choice tests into the modified tic-tac-toe to develop an online formative assessment game with MOG strategy and diverse feedback mechanisms, called tic-tac-toe quiz (TRIS-Q). However, in order to explore whether students using formative assessment game with MOG strategy exhibited better learning performance than those with SOG strategy, the TRIS-Q were developed with two gaming modes: single-player (TRIS-Q-SP) and multi-player (TRIS-Q-MP) versions. Meanwhile, since the feedback mechanism of IEF provides an excessive amount of messages immediately, the authors felt it necessary to examine whether the IEF messages negatively influenced the learning performance or playing enjoyment when the effects of using IEF in assessment games with MOG strategy were unknown. Hence, besides providing the IKR, DKR and DEF in all gaming modes of TRIS-Q, this assessment game was also developed with two different feedback types: immediate elaborated feedback (IEF) and no immediate elaborated feedback (no IEF), and explored whether providing IEF was appropriate.

In summary, this study examined how distinct gaming modes (SOG vs. MOG) and feedback types (IEF vs. no IEF) affected learning effectiveness and participation perceptions in an online learning environment with game-based formative assessment. Firstly, students' learning effectiveness concerning energy knowledge acquisition through an online learning course with different gaming modes and feedback types of online formative assessment was investigated. In addition, since the online formative assessments used in this study were chess-based games, this study also investigated how various gaming modes and feedback types of online formative assessment influenced students' tic-tac-toe ability. Finally, students' participation perceptions concerning playing enjoyment and involvement perception while using different gaming modes and feedback types of game-based formative assessment tool in online learning were explored. The primary research questions (RQ) and hypotheses of the study were as follows:

RQ1 How do distinct gaming modes (SOG vs. MOG) and feedback types (IEF vs. no IEF) in the game-based formative assessment affect student knowledge acquisition? This study expected that MOG and IEF should be better in gaming mode and feedback type for promoting knowledge acquisition than the SOG and no IEF, respectively (Hypothesis 1a). Moreover, there should be an interaction effect between gaming mode and feedback type: The game-based formative assessment should be beneficial to promote knowledge acquisition for students who play MOG gaming mode with IEF feedback type (Hypothesis 1b).

RQ2 How do distinct gaming modes (SOG vs. MOG) and feedback types (IEF vs. no IEF) in the game-based formative assessment affect student tic-tac-toe playing ability? This study expected that MOG and IEF should be better in gaming mode and feedback type for promoting tic-tac-toe playing ability than the SOG and no IEF, respectively (Hypothesis 2a). Moreover, there should be an interaction effect between gaming mode and feedback type: The game-based formative assessment should be beneficial to promote tic-tac-toe playing ability for students who play MOG gaming mode with IEF feedback type (Hypothesis 2b).

RQ3 How do distinct gaming modes (SOG vs. MOG) and feedback types (with IEF vs. no IEF) in the game-based formative assessment influence students' playing enjoyment and involvement perception? This study expected that MOG and IEF should be better in gaming mode and feedback type for promoting both perceptions of enjoyment and involvement than the SOG and no IEF, respectively (Hypothesis 3a). Moreover, there should be an interaction effect between gaming mode and feedback type: The game-based formative assessment should be beneficial to promote both perceptions of enjoyment and involvement for students who play MOG gaming mode with IEF feedback type (Hypothesis 3b).

2. Method

2.1. Experimental design

This study used a 2(SOG vs. MOG) × 2(IEF vs. no IEF) between-subject experimental design, investigating how the two independent variables influenced the dependent variable in an online learning environment. The first independent variable (gaming mode) was divided into two levels: SOG and MOG, for formative assessment. SOG mode means that the opponent is the computer, also known as the non-player character, when students participate in the online game-based formative assessment. The MOG mode means that the opponent is a randomly chosen classmate when students participate in the online game-based formative assessment. The second independent variable (feedback type) was divided into two levels: IEF and no IEF, in online game-based formative assessment. The difference between IEF and no IEF is whether providing immediate elaborated feedback for each question answered in online game-based formative assessment. The dependent variables were learning effectiveness and participation perceptions. Learning effectiveness can be divided into students'

acquisition of energy knowledge and tic-tac-toe ability. These were measured based on the scores that each participant obtained for the energy knowledge test and tic-tac-toe ability test before and after the experiment. The participation perceptions can be divided into playing enjoyment and involvement perception. These were assessed based on questionnaires completed by participants after undertaking the experiment, and were used to understand the level of enjoyment and feelings they experienced. Moreover, in order to avoid the other variables affecting the experimental results, many variables such as the online learning contents, basic feedback types, difficulty of game, playing time, and students' prior knowledge were controlled as the controlled variable. For example, the same online learning contents were equally provided for each experimental group. During playing the game-based formative assessment, the same feedback types including the IKR, DKR and DEF were provided equally for all participants no matter which gaming modes of TRIS-Q they played. Even each experimental group received the same comparative feedback, which means that the TRIS-Q provided the information about top 10 players for each experimental group to lead to the same competitive feelings. Besides, each experimental group received the same difficulty of assessment game, which means that the TRIS-Q-MP or TRIS-Q-SP allows each player gradually to choose an opponent suitable for their playing ability. The experimental time was also all equal for each experimental group. Students' prior knowledge for each experimental group was controlled statistically.

2.2. Participants

The participants consisted of 109 ninth grade students from four junior high school classes in Kaohsiung City, Taiwan. The four classes were randomly assigned to the four groups required for the 2 × 2 factor experimental design. Class A (27 students, 13 males and 14 females, mean age 15.28 years), B (28 students, 15 males and 13 females, mean age 15.18 years), C (27 students, 14 males and 13 females, mean age 15.16 years) and D (27 students, 13 males and 14 females, mean age 15.24 years) were allocated to 'SOG and no IEF', 'MOG and no IEF', 'SOG and IEF' and 'MOG and IEF' groups, respectively.

2.3. Game-based formative assessment environments

This study developed an online learning system for energy education appropriate for junior high school students. The learning materials included three primary units: sources of energy, application of energy, and energy conservation and new energy; they were designed based on the course of living technology in Taiwan. To motivate students to read the learning materials, all online contents were provided with relevant animations and human-like voices reading every word automatically. An online game-based formative assessment with different gaming modes and feedback types was designed in this online learning system, to allow participating students to perform self-assessment whenever they desired.

In order to produce an interesting online formative assessment, the system referred to Hung's (2011) ideal: combining tic-tac-toe with a formative assessment, enabling users to undertake the assessment as if they were playing tic-tac-toe. The process of playing TRIS-Q is shown in Fig. 1. It was identical to that of a standard tic-tac-toe game, in which a player competes either in single-player or multi-player mode against the computer or persons, taking turns to place pieces on a nine-square grid (step 1 of Fig. 1). The first player to form a row, column, or diagonal line wins the game. Regarding the online formative assessment procedure, after each turn the computer randomly

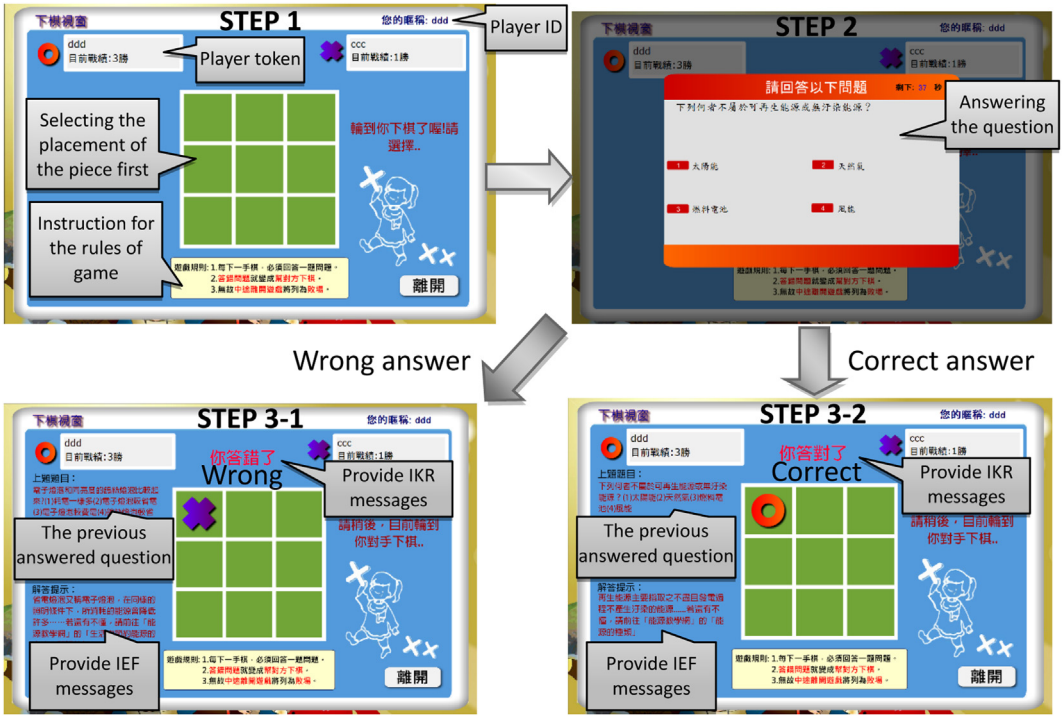

Fig. 1. The three step of playing TRIS-Q.

selects one multiple choice question from the database based on the unit the students were learning (step 2 of Fig. 1). Students were required to answer the question within a set time frame (40 s). Because the first player always plays an offensive role in the tic-tac-toe, this study slightly modified the original rules of tic-tac-toe in order to enhance the gameplay difficulty. When a student answered a question incorrectly, the student would have to make a move for the other party (step 3-1 of Fig. 1). Players could only place their own pieces when they answered correctly (step 3-2 of Fig. 1). This modification allowed the offensive and defensive roles to change at any time, encouraging participants to thoughtfully answer the assessment questions, thereby increasing the difficulty and amusement generated by the game.

The game rules of TRIS-Q-SP and TRIS-Q-MP were the same, as mentioned above. However, in TRIS-Q-SP, the player can only play the game against the computer. Nevertheless, the levels of difficulty of game (easy and hard) are decided by the player. The easy level in TRIS-Q-SP means that the computer's tic-tac-toe ability is poor, and vice versa. On the other hand, in TRIS-Q-MP, a player can only play the game against another player. TRIS-Q-MP provides a game lobby (Fig. 2) that allows students to pair with other participants. Players can establish a game and wait for a second person to join, or choose to join another person's game.

Additionally, both TRIS-Q-SP and TRIS-Q-MP provided two consistent feedback conditions. As mentioned above, one condition integrated diverse feedback types in TRIS-Q-SP and TRIS-Q-MP for the experiment groups 'SOG and IEF' and 'MOG and IEF', including IKR, IEF, DKR and DEF. The other condition removed IEF from TRIS-Q-SP and TRIS-Q-MP for the experiment groups 'SOG and no IEF' and 'MOG and no IEF', including only IKR, DKR and DEF. Step 3 of Fig. 1 shows IKR and IEF. An IKR message will be shown on the right side of game screen to remind players about the correctness of previous questions when students finish answering a question in TRIS-Q-SP or TRIS-Q-MP. Also, the left side of the game screen will show the previous question and IEF feedback to offer relevant data and clues from previous questions when students finish answering a question in TRIS-Q-SP or TRIS-Q-MP. Moreover, DKR and DEF will be provided to students when they use the query answering history function after completing a game. As shown in Fig. 3, the answering records show the DKR on the right side for all the answered questions, i.e. whether they are correct. Students can also select one of the answered questions to see its DEF message, shown at the top of Fig. 3, in the answering records. In addition, in order to enhance learner motivation to use game-based formative assessments and encourage them to improve their performances, both TRIS-Q-SP and TRIS-Q-MP provide a high score list function, showcasing the top 10 game performances and the top 10 players who obtained high correct answer ratios.

2.4. Procedure

Before participating in this experiment, all of the participants were asked to complete energy knowledge and tic-tac-toe ability pretests. After a quick training concerning how to use the online learning course and formative assessment game, all of the participants were compelled to take responsibility for being familiar with one learning topic per week from three major learning units in the online learning platform for eight class periods (45 min each) over four week period. In the final week of the experiment, they were asked to revise all of the learning themes. In order to prevent the participants from spending too much time playing the formative assessment game without browsing the online learning contents, the teachers asked them to read the contents for at least 30 min before they started to undertake a game-based formative assessment activity, based on the suggestions proposed by Tsai, Kinzer, Hung, Chen, and Hsu (2013). After the entire online learning session, all of the participants took the energy knowledge and tic-tac-toe ability posttests. Finally, a questionnaire on participation perceptions was distributed to participants.

2.5. Measures

2.5.1. Energy knowledge performance

An energy knowledge test was constructed based on the online learning contents, in order to examine student energy knowledge before and after the online learning activity. The test was composed of 40 multiple-choice items (see Appendix A.). To maintain validity and reliability of all items, two junior high school teachers inspected all items' content validity, and a KR-20 reliability coefficient of .85 was obtained through a pre-examination study with 58 ninth-grade students. Besides, to evaluate the difficulty and discrimination of all items, an item analysis was conducted, and the average difficulty of .70 and discrimination of .39 were obtained.

2.5.2. Tic-tac-toe ability

This study adopted the tic-tac-toe ability test developed by Crowley and Siegler (1993) in order to understand the changes in playing ability following multiple rounds of tic-tac-toe-based assessment games. The test consisted of 16 questions; the total score was 16; each

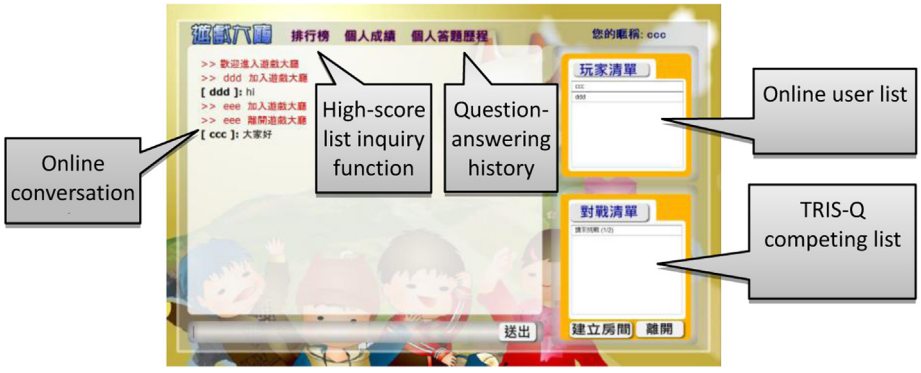

Fig. 2. The game lobby of the TRIS-Q-MP.

Fig. 3. The delayed feedback provided in TRIS-Q-SP or TRIS-Q-MP.

question involved an incomplete tic-tac-toe game, and students were required to select the optimal move (see Appendix B.). According to Crowley and Siegler, tic-tac-toe players must possess four major chess-playing skills to transition from beginners to professionals: (a) know how to win: when an opportunity appears to make a three-piece line, players can identify the correct position; (b) know how to block: when an opportunity appears for the opponent to make a three-piece line, the player can identify the correct position to block the opponent from winning; (c) know how to make a fork: when an opportunity appears for making 2 three-piece lines, the player can identify the correct position; and (d) know how to block a fork: when an opportunity appears for the opponent to make 2 three-piece lines, the player can identify the correct position for placing the piece to block the fork. Thus, this test assesses four tic-tac-toe skills (win, block, fork and block fork). Of all 16 questions, every four questions were related to one of the four tic-tac-toe skills (highest possible score for each skill is 4). A research professional who specialized in chess games reviewed the appropriateness of the test, and a KR-20 reliability coefficient of .71 was obtained through a pre-examination study with 58 ninth-grade students.

2.5.3. Participation perceptions

This study used a self-developed questionnaire on participation perceptions to understand the enjoyment and involvement perception in the game-based formative assessment; the enjoyment scale of Downs and Shyam Sundar (2011) was used as a primary reference. The students rated their perceptions on a 5-point scale that ranged from strongly agree (5) to strongly disagree (1). The items of enjoyment perception were: (1) I enjoyed playing TRIS-Q; (2) I enjoyed the feeling of competition in TRIS-Q; (3) I acquired exciting game experience from TRIS-Q; (4) Playing games similar to TRIS-Q in the future will make me happy. The items of involvement perception were: (1) I like the way I can play the game while taking the test; (2) This kind of game makes me want to answer the questions thoughtfully; (3) I can recognize the areas I failed to learn well through the game; (4) I attempted to find the answer I did not know through the game; (5) I think this game benefits my learning. The Cronbach α for the entire scale was 0.91, and the Cronbach α for playing enjoyment and involvement perception of the subscale were 0.84 and 0.90, respectively. Besides the 5-point style items described above, an open-ended item was provided at the end of questionnaire to allow students to leave other comments toward the TRIS-Q.

3. Results

3.1. Effects on student knowledge acquisition

In order to identify how distinct gaming modes (SOG vs. MOG) and feedback types (IEF vs. no IEF) in the game-based formative assessment affected knowledge acquisition (RQ 1), this study conducted a two-way analysis of covariance (ANCOVA) using gaming mode and feedback type as the independent variables, the pretest scores for the energy knowledge test as the covariate variable, and the posttest scores as the dependent variable. Before undertaking ANCOVA, the assumption of homogeneity of regression was tested ($F(3, 101) = .29$, $p = .835$) and was not violated. The results of the two-way ANCOVA showed that no interaction existed between the two factors of gaming mode and feedback type ($F(1, 104) = .061$, $p = .805$). Thus, Hypothesis 1b was not confirmed. The main effect of the variable gaming types yielded a test result of $F(1, 104) = 1.186$, $p = .279$, which did not attain significance, suggesting that after eliminating the effects of the covariate, the gaming mode (SOG and MOG) used in the game-based formative assessment did not significantly affect the effectiveness of energy knowledge acquisition. The main effect of feedback type generated a result of $F(1, 104) = 8.307$, $p = .006$, $\eta^2 = .072$, which attained significance; this indicated that after eliminating the effects of the covariate, the feedback type (IEF and no IEF) of the game-based formative assessment significantly affected the effectiveness of energy knowledge acquisition. Furthermore, after a post-hoc test of the main effect, the adjusted mean score of the posttest for the IEF group (76.54) was significantly better than those for the no IEF group (72.09). The results indicated that providing IEF messages in TRIS-Q had a better learning impact on student knowledge acquisition than not providing IEF messages. Hence, Hypothesis 1a was only partially confirmed.

Furthermore, in order to verify the above results, this study analyzed how distinct gaming modes and feedback types affected the students' correct answer ratios in TRIS-Q because the values of correct answer ratios could reflect students' knowledge acquisition based on the significant Pearson correlation between each student's ratio of correct answers in TRIS-Q and their energy knowledge posttest score ($r = .662$, $p = .000$). Thus, a two-way ANOVA was conducted to explore how different gaming modes and feedback types affected students' correct answer ratios in TRIS-Q. Before undertaking ANOVA, the assumption of homogeneity of variance was tested (Levene's test: $F(3, 105) = 1.793$, $p = .153$) and was not violated. The results showed that no interaction existed between the two factors of gaming mode and feedback type ($F(1, 105) = .057$, $p = .812$). The main effect of gaming mode ($F(1, 105) = 1.302$, $p = .256$) did not attain significance, implying that different gaming modes (SOG and MOG) did not significantly affect the correct answer ratio. The main effect of feedback type ($F(1, 105) = 7.191$, $p = .009$) attained significance. The post-hoc test results showed that after adjusting the average, the IEF groups attained a

significantly higher average correct ratio (.78) than did the no IEF groups (.72). This implies that providing IEF messages during the TRIS-Q was more beneficial in enhancing the correct ratio than was not providing IEF messages. Because the correct answer ratio was positively related to the energy knowledge posttest score, this finding suggests that IEF messages provided during TRIS-Q game facilitated enhancing learner energy knowledge.

3.2. Effects on student tic-tac-toe ability

To explore the differences in tic-tac-toe ability among distinct groups (RQ 2), this study conducted a two-way analysis of covariance (ANCOVA) using gaming mode and feedback type as the independent variables, and the tic-tac-toe ability pretest and posttest scores as the covariate and dependent variables, respectively. Before undertaking ANCOVA, the assumption of homogeneity of regression was tested ($F(3, 101) = 1.13$, $p = .341$) and was not violated. The results of the two-way ANCOVA showed that no interaction existed between the two factors of gaming mode and feedback type ($F(1, 104) = .715$, $p = .400$). Thus, Hypothesis 2b was not confirmed. The main effect of the variable game types yielded a test result of $F(1, 104) = 1.270$, $p = .262$, which did not attain significance, suggesting that after eliminating the effects of the covariate, the gaming mode (SOG and MOG) used in the game-based formative assessment yielded no significant difference in the improvement of tic-tac-toe ability. By contrast, the main effect of feedback type ($F(1, 104) = 6.455$, $p = .013$, $\eta^2 = .058$) attained significance, indicating that after eliminating the effects of the covariate, the feedback type (IEF and no IEF) used in the game-based formative assessment yielded significant difference in the improvement of tic-tac-toe ability. According to the post-hoc test on the main effect, the adjusted mean for the IEF group was 13.05, which was significantly higher than the 12.19 attained by the no IEF group. In other words, providing IEF messages, as opposed to no IEF, facilitated the improvement of students' tic-tac-toe ability. Hence, Hypothesis 2a was only partially confirmed.

Moreover, to explore why the IEF affected the improvement of tic-tac-toe ability, this study further analyzed the participant scores of the four tic-tac-toe skills in the tic-tac-toe ability test. Table 1 presents the scores of the tic-tac-toe test for the four tic-tac-toe skills in each group, indicating that the average pretest scores for the win and block questions were significantly high. However, the average scores for the questions related to fork and block fork were significantly low. These findings were consistent with those of Crowley and Siegler (1993), who suggested that fork and block fork skills were advanced chess techniques. Moreover, by using gaming mode and feedback type as the independent variables, and the pretest and posttest scores for one of the tic-tac-toe skills as the covariates and dependent variables, respectively, a two-way ANCOVA was conducted on the scores for the four tic-tac-toe skills. The results found that only the fork skill attained significance in the main effect test of feedback type ($F(1, 104) = 4.000$, $p = .048$, $\eta^2 = .037$). The other skill scores did not attain significance. Therefore, after eliminating the effects of the covariates, the IEF feedback type used in the game-based formative assessment had significantly better effect on the effectiveness of acquiring the tic-tac-toe fork skill than the no IEF did. This result supported the finding that providing IEF messages enhanced the effectiveness of acquiring tic-tac-toe playing skill, and also reinforced the understanding that this enhancement is attributed to the improved fork skill.

3.3. Effects on student participation perception

At first, game and feedback types were regarded as independent variables, and enjoyment perception score was used as the dependent variable for the two-way ANOVA analysis to determine whether students using differing gaming modes or feedback types exhibited differences in their enjoyment perceptions regarding the assessment game (RQ 3). Before undertaking ANOVA, the assumption of homogeneity of variance was tested (Levene's test: $F(3, 105) = 1.504$, $p = .218$) and was not violated. The results showed that no interaction existed between the two factors of gaming mode and feedback type ($F(1, 105) = .005$, $p = .946$). The main effect of gaming mode ($F(1, 105) = .126$, $p = .723$) did not attain significance. The post-hoc test results showed that after adjusting the average, the average scores of SOG and MOG groups on the enjoyment scales were 3.59 and 3.53 respectively. The results suggested that the gaming mode (SOG and MOG) used in the game-based formative assessment did not significantly affect the enjoyment perception that learners experienced when playing the game. The main effect of feedback type ($F(1, 105) = .655$, $p = .420$) also failed to attain significance. The post-hoc test results showed that after adjusting the average, the average scores for no IEF and IEF groups on the enjoyment scales were 3.63 and 3.49 respectively. The results suggested that the different feedback types (IEF and no IEF) also did not significantly affect learner enjoyment.

Additionally, game and feedback types were used as independent variables, and involvement perception score was used as the dependent variable for the two-way ANOVA analysis, in order to determine whether students using differing gaming modes or feedback types exhibited differences in their involvement perceptions regarding the game-based assessment (RQ 3). Before undertaking ANOVA, the assumption of homogeneity of variance was tested (Levene's test: $F(3, 105) = 1.207$, $p = .311$) and was not violated. The results of the two-way ANOVA showed that no interaction existed between the two factors of gaming mode and feedback type ($F(1, 105) = .195$, $p = .620$). The main effect of gaming mode ($F(1, 105) = .001$, $p = .980$) did not attain significance. The post-hoc test results showed that after adjusting the average, the average scores of SOG and MOG groups on the involvement scales were all 3.86. The results suggested that the gaming mode (SOG and MOG) used in the game-based formative assessment did not significantly affect learner involvement perceptions. The main effect

Table 1
Pretest and posttest scores for the four skills in the tic-tac-toe ability test.

	Win		Block		Fork		Block fork	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
SOG & no IEF ($n = 27$)	3.89	4.00	3.78	3.85	2.37	2.11	3.00	2.48
MOG & no IEF ($n = 28$)	3.93	3.93	3.82	3.79	2.14	2.14	2.57	2.39
SOG & IEF ($n = 27$)	3.85	4.00	3.85	3.93	2.00	2.30	2.19	2.22
MOG & IEF ($n = 27$)	4.00	3.96	4.00	3.93	1.89	2.74	2.44	2.70

of feedback type (F (1, 105) = .652, p = .421) also failed to attain significance. The post-hoc test results showed that after adjusting the average, the average scores of no IEF and IEF groups on the involvement scales were 3.79 and 3.93 respectively. The results suggested that the feedback types (IEF and no IEF) used in the game-based formative assessment also did not significantly affect learner involvement perceptions. Hence, Hypothesis 3a and Hypothesis 3b were all not confirmed.

Furthermore, in the open-ended questions on the scale, students provided positive comments on game. For example, the students stated "I think the game is exciting," "The game is entertaining", "Questions accompanied by tic-tac-toe games were very interesting. They were not boring anymore and I could learn a lot. I hope our future study material can be accompanied by games because I'll be able to remember the content more easily", "My deepest impression of the game was the sense of accomplishment I felt in maintaining a position on the high score list" and "The learning style was different. We always learned by rote memorization before, but this learning method incorporated tic-tac-toe games so I could recognize the parts I was not familiar with and reevaluate the parts I did not know." Based on the ANOVA results and the various comments in the open-ended questions, the findings implied that most students found the game interesting, and that it facilitated learning no matter what gaming mode and feedback type was used.

4. Discussion

This study proposed an online learning system for energy education, modified the typical rules of tic-tac-toe and incorporated multiple choice tests into the game to develop a game-based formative assessment tool for an online learning course. In order to explore how different gaming modes and feedback types in this game-based formative assessment affected knowledge acquisition effectiveness and participation perceptions, two gaming modes (SOG and MOG) and two feedback types (IEF and no IEF) of TRIS-Q were developed. Furthermore, a 2(SOG vs. MOG) × 2(IEF vs. no IEF) between-subject experiment was conducted to investigate the effects on 109 ninth-grade students from four classes of junior high school, over an experiment period of eight class periods.

After the experiment, according to the results of the two-way ANCOVA, different gaming modes and feedback types in game-based formative assessment affected student knowledge acquisition differently. Different gaming modes (SOG and MOG) did not affect the effectiveness of knowledge acquisition, while distinct feedback types did. No matter which gaming modes of TRIS-Q students played, the participants who received the assessment game with IEF messages showed significantly higher scores in the energy knowledge posttest than those who received no IEF. Also, according to the result of the two-way ANOVA on how different gaming modes and feedback types affected students' correct answer ratios in TRIS-Q, IEF messages provided during TRIS-Q game facilitated enhancing learners' correct answer ratios in TRIS-Q. The above findings indicated that proving immediate elaborated feedback in online game-based formative assessment promoted learning. The positive impact of IEF in this study was identical to previous research which suggested that IF and EF messages promoted learning (Dihoff et al., 2003; Krause, Stark, & Mandl, 2009; Meyer et al., 2010; Shute, Hansen, & Almond, 2007; Van der Kleij et al., 2011). It was also consistent with the result of previous studies (Erhel & Jamet, 2013; Mayer & Johnson, 2010; Wouters & van Oostendorp, 2013), which had indicated providing regular feedback and explanative feedback improved learning in game-based learning environments.

Besides the positive effect of IEF in TRIS-Q on the effectiveness of knowledge acquisition and correct answer ratio, this study also found that the mechanism of IEF improved students' tic-tac-toe ability. According to the two-factor ANCOVA results, the tic-tac-toe posttest scores of the IEF group were higher than those of the no IEF group. Also, according to the analysis results of students' performance of the four tic-tac-toe skills in the tic-tac-toe ability test by two-way ANCOVA, it was found that IEF feedback type used in the game-based formative assessment affected the improvement of students' fork skill. Because very few studies have used IEF to promote tic-tac-toe ability, this result could not be compared to previous research. However, based on the rules of TRIS-Q and the above findings, it seems clear why the IEF affected the improvement of tic-tac-toe ability. According to the traditional rules of tic-tac-toe, the player who makes the first move has a better chance to win and use the fork skill, whereas the opponent who makes the second move can only play the defensive role, and has the chance to practice the block fork skill. However, after the rules of the tic-tac-toe game were modified in TRIS-Q, the offensive role was only given to the players who answered questions correctly before making a move, and the offensive and defensive roles could thus be switched at any time when a player answered a question incorrectly. In other words, only the player who had a high correct answer ratio had the opportunity to practice the fork skill. When players had a low correct answer ratio, they could not even be effective defenders and practice the block fork skill because they made a move for their opponents. Therefore, the participants who had a high correct answer ratio may have had numerous opportunities to practice and thereby improve the fork skill. Because the previous results indicated that IEF messages enhanced the correct answer ratio during the TRIS-Q game, the students from the IEF groups had more opportunities to practice the fork skill than did the students in the no IEF groups. Thus, IEF positively affected the improvement of tic-tac-toe ability.

Furthermore, according to the average scores on the participation perceptions scale, most students showed positive attitude toward TRIS-Q; the average scores for all students on the enjoyment and involvement scales were 3.56 and 3.86, respectively. The students' comments provided in the open-ended question of participation perceptions scale also showed that most students expressed a positive attitude toward TRIS-Q. Additionally, according to the ANOVA results, the gaming mode and feedback mechanism used during the game exhibited no significant difference in the sense of enjoyment and involvement perceptions. The findings imply that most students found the game interesting, and that it facilitated learning, no matter what gaming mode and feedback type was used. However, unexpectedly, the findings indicated that the students did not feel any more excited when their opponent was a real person than they did when their opponent was a computer. This seems to differ from previous studies (Lim & Reeves, 2010; Mandryk, Inpken, & Calvert, 2006; Weibel, Wissmath, Habegger, Steiner, & Groner, 2008), indicating that players who compete against real people in competitive games experience a higher level of physiological motivation than do players whose opponents were computers. This may be because the TRIS-Q-MP is not a pure multiplayer game like commercial multiplayer role playing or competitive games, and player enjoyment perceptions might therefore differ. Also, the single-player game (TRIS-Q-SP) in the current study took place in an Internet environment, and a high score list was provided, allowing participants to be immediately aware of record changes. That is, the characteristic of synchronous competition among players was also incorporated into the SP game. This may have resulted in differences in the participant perceptions compared with people who played pure SOG.

5. Conclusion and future work

In summary, the TRIS-Q, regardless of gaming mode and feedback type, proposed in an online learning course facilitated learning and promoted positive participation perceptions. However, based on the various statistical results, the different gaming modes (SOG and MOG) of TRIS-Q did not significantly affect learning effectiveness and participation perceptions, while the different feedback types (IEF and no IEF) significantly affected learning effectiveness. The result implies that the best design for the proposed tic-tac-toe-based assessment game was to provide IEF for each question in TRIS-Q. This design facilitated the enhancement of both energy knowledge acquisition and student tic-tac-toe ability when comparing it with the feedback type of no IEF. Besides, participants' enjoyment was not influenced by these feedback messages.

Despite this study derived the research findings from careful experiment, some improvements can be made in future studies. Firstly, although the TRIS-Q-SP or TIRS-Q-MP allowed participants to choose their opponent's skill by themselves, inappropriate selection of game difficulty could affect learning effectiveness and participation perceptions. In order to examine the accuracy of this study, future studies should verify whether there existed difference related to the selection of game difficulty among four experiment groups, and deeply investigate the influence of inappropriate selection of game difficulty. Besides, although this study provided equal time to participate the online course for each experimental group, different participation times on playing assessment game and browsing online learning contents could affect learning effectiveness and participation perceptions. To examine the findings of this study, the playing times and reading times in each group should be analyzed and compared circumspectly in future studies. The TRIS-Q proposed in this study also can be employed in other online courses to check whether obtaining the same findings in the future. Meanwhile, future studies can increase the number of samples to inspect if much bigger sample size also leads to the same results. Several post-tests also can be done to measure the impact of the different types of feedback on the students' long term memory. Alternatively, games that incorporate quiz assessment may have flaws that require additional investigation. For example, for extremely difficult games, future researchers should extensively examine whether solving difficult problems in the games, while attempting to answer test questions, would increase the cognitive load excessively and exert a negative effect.

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Appendix A. Sample items of energy knowledge test

The items related to sources of energy:

What is the source of energy for the Earth?
(A) oil
(B) coal
(C) geothermal energy
(D) solar energy

Which kind of the following non-renewable energies causes the least damage to the environment?
(A) diesel oil
(B) machine oil
(C) natural gas
(D) coal

The items related to application of energy:

Which one has the maximum generating capacity in Taiwan?
(A) thermal power generation
(B) nuclear Power generation
(C) hydropower generation
(D) wind power generation

Which one is not the disadvantage of hydropower generation?
(A) ecological destruction
(B) flooding
(C) affection by the rainy season
(D) requiring damming and resettlement

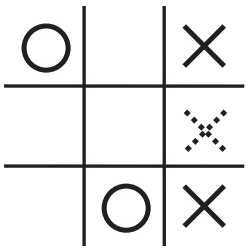
The items related to energy conservation and new energy:

What kind of light bulb used at home saves the power the most?
(A) fluorescent lamp
(B) energy-saving lamp (electronic lamp)
(C) LED lamp (light-emitting diode)
(D) halogen lamp

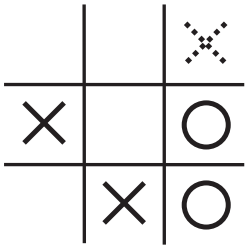
What is the new energy known as “the most reliable and perfect energy for human”?
(A) hydrogen energy
(B) helium energy
(C) uranium energy
(D) titanium energy

Appendix B. Sample items of tic-tac-toe ability test (correct moves are indicated by the dashed X)

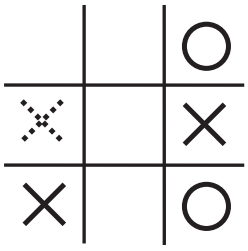
The item related to “win” skill:



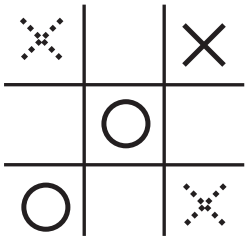
The item related to “block” skill:



The item related to “fork” skill:



The item related to “block fork” skill:



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