The Development and Evaluation of an Online Formative Assessment upon Single-player Game in E-learning Environment

Fu-Hsing Tsai[1,*]

[1]Teacher Education Center, National Chiayi University, Chiayi County, Taiwan

*Correspondence: Teacher Education Center, National Chiayi University, 85, Wunlong Village, Minsyong, Chiayi County, Taiwan. Tel: 886-5-226-3411. E-mail: fhtsai@mail.ncyu.edu.tw

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Abstract

This study developed a game-based formative assessment, called tic-tac-toe quiz for single-player version (TRIS-Q-SP), in an energy education e-learning system. This assessment game combined tic-tac-toe with online assessment, and revised the rule of tic-tac-toe for stimulating students to use online formative assessment actively. Additionally, to investigate which types of formative feedback were appropriate for use in this game-based formative assessment, immediate elaborated feedback (IEF) and no immediate elaborated feedback (NIEF) mechanisms were designed and incorporated in TRIS-Q-SP. The findings revealed that all participants improved their energy knowledge through the e-learning system, and expressed enjoyment and positive opinions toward the TRIS-Q-SP. However, the various statistical results suggested that providing IEF for each question answered in TRIS-Q-SP was the optimal design. This design facilitated the enhancement of energy knowledge acquisition when comparing it with NIEF condition, and did not affect all participants' enjoyment perceptions.

Keywords: *formative assessment; game-based assessment; e-learning*

1. Introduction

With the development of technology, instruction and learning through computers and the Internet has become an new educational trend in the world (Bentley, Selassie, & Shegunshi, 2012); more than 10 terms (Brown, Charlier, & Pierotti, 2012), such as distance learning, online learning, blended learning, mobile learning, and e-learning, which is to refer to instruction and learning delivered through computer technology, have evolved from this trend. In other words, educational courses are no longer confined to only traditional classrooms because online courses are also offered by schools and enterprises in contemporary educational systems. For example, more than 31 percent of U.S. college students took at least one online course in 2010 (Allen & Seaman, 2011).

Online assessment is an important component in current e-learning systems (McKimm, Jollie, Cantillon, 2003), particularly, online formative assessment tools play a crucial role in e-learning environments. The tool can automatically present questions and scores and quickly provide feedback, immediately informing students of their learning performance (Liu, Wang, & Zhang, 1999). The tool also provides opportunities for enhancing system interactions when learners engage in individualized learning (McKimm, Jollie, & Cantillon, 2003; Vasilyeva, Pechenizkiy, & De Bra, 2008). Previous studies have suggested that providing online formative assessments undoubtedly improves e-learning motivation and effectiveness (Gardner, Sheridan, & White, 2002; Henly, 2003; Khan, Davies, & Gupta, 2001). However, a related study indicated that not every online learner maintains their high motivation for using online formative assessment in online courses (Buchanan, 2000; Henly, 2003). In other words, although online formative assessment allows opportunities to repeat tests or practice at convenient times, certain learners could continue testing after attempting once or twice, specifically when learners were constantly presented with boring multiple choice tests. Thus, enhancing participation in online formative assessments has become a critical research topic (Costal, Mullan, Kothe, Butow, 2010; Lin & Lai, 2013).

To address these problems, online formative assessments could combine games with assessments to enhance the participation ratio for using online formative assessments when numerous scholars (Vogel et al., 2006; Yang, Chien, & Liu, 2012) have claimed that game-based learning can enhance learning motivation and effectiveness. Although

some scholars (Tsai, 2013; Wang, 2008) have employed game-based formative assessments in e-learning, research regarding this topic is scarce. Tsai (2013) combined multiple choice tests with multi-player tic-tac-toe game to be an online formative assessment (called as TRIS-Q) in e-learning environment, and indicated that students' learning effectiveness was enhanced after using online learning and game-based assessment. However, this study also found some drawbacks arised from a multi-player formative assessment, and suggested a single-player tic-tac-toe assessment game should be developed.

Based on Tsai's (2013) suggestion, this study attempted to develop a single-player formative assessment game, called tic-tac-toe quiz for single-player version (TRIS-Q-SP), in an e-learning system targeting knowledge of energy education. Basically, TRIS-Q-SP adopted the TRIS-Q's game rules proposed by Tsai. However, in TRIS-Q-SP, a player only can play tic-tac-toe game against the computer, also known as the Artificial Intelligence (AI), with two levels of difficulty (easy and hard). Additionally, to provide effective feedbacks in formative assessment, TRIS-Q-SP adopted diverse types of formative feedback by referring to relevant studies (Shute, 2008) of formative feedback. The primary feedback comprised immediate feedback, delayed feedback, knowledge of results (KR), which inform learners of whether their answer is correct or incorrect, and elaborated feedback (EF), which present a detailed message, providing information and clues relevant to the question to guide learners toward the correct answers.

Although various formative assessment studies (Van der Kleij, Timmers, & Eggen, 2011) have suggested that EF improves learning effectiveness, the immediate elaborated messages in TRIS-Q-SP may annoy game participants. Students could focus on completing game without reading the immediate elaborated messages in-game. Therefore, assuming that whether immediate EF negatively affects game-based assessments is unknown, this study adopted two types of immediate EF in TRIS-Q-SP, namely, immediate EF (IEF) and no immediate EF (NIEF), and subsequently explored how distinct feedback types affected the effectiveness of and sense of involvement in TRIS-Q-SP. Regarding e-learning effectiveness, the study primarily investigated how various feedback types of game-based formative assessment influenced the acquisition of energy knowledge. Concerning sense of involvement, the researchers primarily explored learner enjoyment after using the game-based formative assessment tool.

2. The E-Learning Environment and TRIS-Q-SP

This study involved Flash, ActionScript, and database technologies, which were used to develop an e-learning system and TRIS-Q-SP on energy education appropriate for junior high school students. The course material was designed based on the textbooks used in Taiwan. The contents were divided into three major themes: sources of energy, application of energy, saving energy and development of new energy. Figure 1 shows the e-learning menu for sources of energy, which lists relevant materials for students to learn, explaining various sources of energy. After the learner selected the material, human-like voice or relevant animations appeared to captivate the learning interest of the students.

Figure 1: The E-Learning for Energy Education

TRIS-Q-SP was designed in this e-learning system to allow learners to participate whenever they desire. Learners could select the button for entering the online assessment in e-learning system (as shown in Figure 1) and conveniently enter the main menu of TRIS-Q-SP (Figure 2). When learners enter the TRIS-Q-SP, they could click the

different buttons (as shown in Figure 2) for entering a low level game, starting a high level game, querying the high score list, querying the personal score, or querying answering history.

Figure 2: The Game Menu of TRIS-Q-SP

As soon as learner evokes a new game, the game-based formative assessment starts shown as step 1 of Figure 3. The game rule is similar to the traditional tic-tac-toe game, namely, the first player to place three tokens in a row, column, or diagonal is the winner. However, this game changes some rules of traditional tic-tac-toe. That is, when a player takes his turn, the game will randomly pop a multiple-choice quiz which was selected randomly from database according to the e-learning contents, shown as step 2 of Figure 3. Since the victory always goes to the one who makes the first move in tic-tac-toe, in order to increase the difficulty and playfulness, the game rule is slightly modified. If the player responses the right answers, he can place his token (step 3 of Figure 3); otherwise he will place his opponent's token (step 3 of Figure 3). Thus, the new game rule could stimulate participants to seriously answer the questions in TRIS-Q-SP.

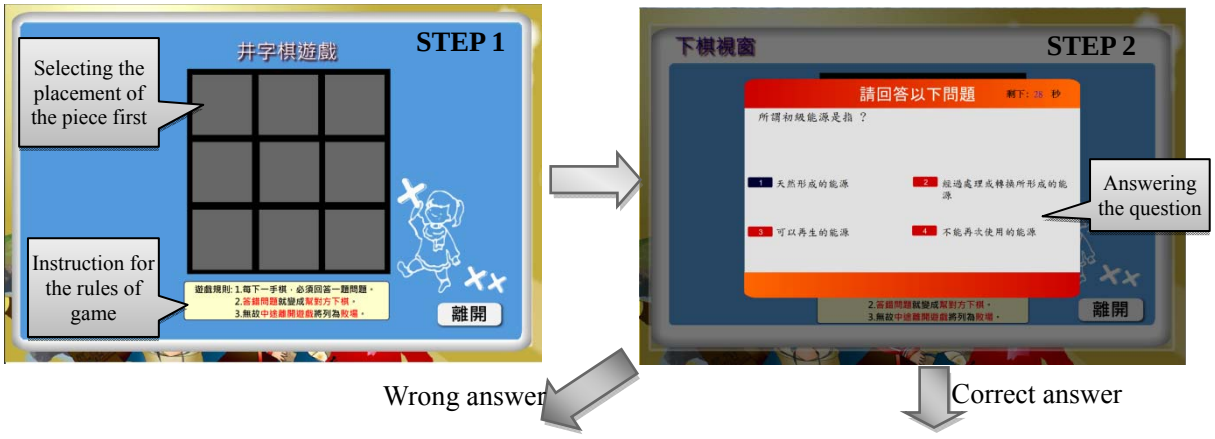

Figure 3: The Process of Playing TRIS-Q-SP and Immediate Feedback

Additionally, the TRIS-Q-SP integrated diverse types of formative feedback, such as immediate KR (IKR), immediate EF (IEF), delayed KR (DKR), and delayed EF (DEF). The step 3 of Figure 3 shows the screen that appeared when students finished answering a question and made a move in the TRIS-Q-SP. An IKR feedback showed on the right side of the screen, informing the students if they answered the previous question correctly. The previous question and IEF feedback also showed on the left side of the screen, offering relevant data and clues to the previous question. However, during the game, participants concentrating on the TRIS-Q-SP may neglect the IEF messages. To prevent the IEF messages from disturbing the students' flow, one group did not receive immediate EF during the experiment. Figure 4 shows the screen that appeared when students entered the function of querying answering history in TRIS-Q-SP. The screen clearly displayed all the answered questions and detailed records regarding whether answers were correct (DKR). A DEF message also showed on the top side of the screen, offering relevant data and clues to the answered question.

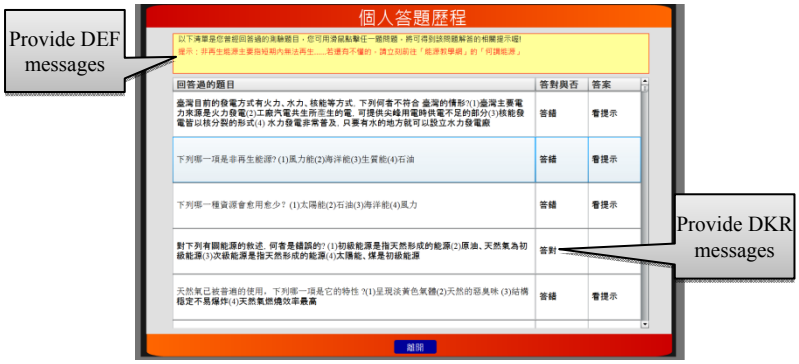

Figure 4: The Delayed Feedback Provided in the TRIS-Q-SP

3. Method

3.1 Participants and Procedures

This research used the quasi-experiment study method. Fifty-five ninth-grade students selected from two classes of a junior high school in Taiwan, participated in this experiment; each class included 27 and 28 students respectively. In the experiment, all participants were randomly assigned by class to two groups: 'immediate elaborated feedback' group (IEF group, N=27, 14 males and 13 females) and 'no immediate elaborated feedback' group (NIEF group, N=28, 14 males and 14 females).

The study duration was eight class periods (45 min each) that lasted for 4 weeks. Prior to participating in the e-learning activity, all participants were asked to complete energy knowledge pretest. After a brief introduction about how to log in to the e-learning system and how to play the TRIS-Q-SP, students were instructed to engage with one learning topic per week according to the three major learning themes in the e-learning system. In last week of the experiment, the students were asked to comprehensively revise for the all learning themes. To prevent the students from engaging in the TRIS-Q-SP without reading the e-learning contents, the suggestions of Tsai, Kinzer, Hung, Chen, and Hsu (2013) were followed. When beginning a new learning topic, the teachers asked the students to read the e-learning materials for at least 30 minutes before engaging in the TRIS-Q-SP based on their grouping conditions.

After completing the e-learning activity, all participants were asked to complete energy knowledge posttest and a questionnaire regarding their enjoyment perception of playing TRIS-Q-SP.

3.2 Instruments

3.2.1 Energy Knowledge Test

To understand how student knowledge was affected after completing the e-learning activity, energy knowledge test was developed based on the content of the e-learning material. The test comprised 40 multiple-choice questions and the total score was 100. Two junior high school teachers vetted all items' content validity, and the reliability was assessed by internal consistency (Kuder-Richardson 20, KR-20) through a pilot study with 58 ninth-grade students before the experiment. A KR-20 reliability coefficient of .85 was obtained.

3.2.2 Questionnaire of Enjoyment Perception

This study developed a questionnaire to measure students' enjoyment perception regarding the two feedback conditions of TRIS-Q-SP. A 5-point Likert-type scale consisting of 4 items was developed by referring to the enjoyment scale of Down and Sunder (2011). To understand the authentic perceptions of the participants after using the game-based formative assessment, an open-ended item was also included for this questionnaire. It allowed the students to record their opinions and suggestions toward the TRIS-Q-SP. The Cronbach's α of the inventory was .83.

4. Results

4.1 Effects on Knowledge Acquisition

To examine how the e-learning course affected student knowledge acquisition, the energy knowledge pretest and posttest scores were employed in a paired sample *t*-test. Based on analysis of paired sample *t*-test, the energy knowledge pretest and posttest scores significantly differed for the NIEF group (t (27) = 6.722, p = .000), indicating that the posttest scores (M = 75.54, SD =14. 15) were significantly higher than the pretest scores (M = 63.68, SD =15.49). The energy knowledge pretest and posttest scores also exhibited significant differences in the IEF group (t (26) = 14. 862, p = .000), indicating that the posttest scores (M = 74.17, SD = 13.27) were significantly higher compared with the pretest scores (M = 56.20, SD = 12). Based on these statistical data, all groups substantially improved their average energy knowledge assessment scores, regardless of which formative feedback they received. Figure 5 displays the score improvements for each group of students.

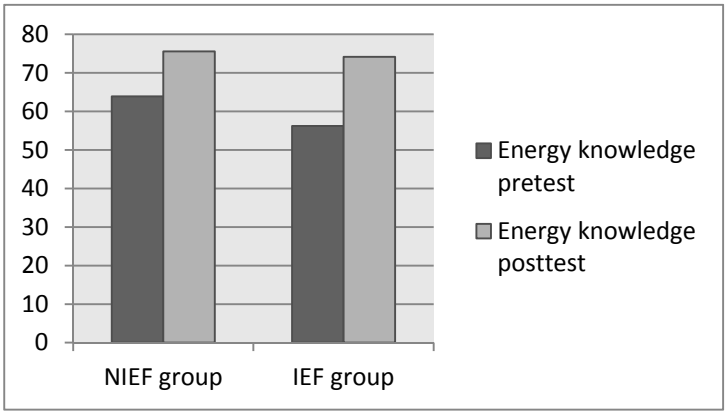

Figure 5: A Comparison of the Energy Knowledge Test Scores for the Two Groups

To compare the learning effects between two formative feedback conditions in a game-based formative assessment, a one way analysis of covariance (ANCOVA) was employed to examine the differences between energy knowledge posttest scores of the two groups with subjects' pretest scores as covariate. The test of homogeneity of regression showed that the homogeneity of regression of the two groups was not different (F (1,51) = .312, p = .579), indicating that the coefficient is homogeneous and fits the basic assumption of the ANCOVA. The results of ANCOVA indicated that after the influence of covariate was controlled, the post-test scores of the two groups were significantly different (F *(1,52)* = 4.594, p = .037, η^2 =. 081). Furthermore, the post-hoc test indicated that after adjusting the mean, the average score of the energy knowledge posttest for the IEF group was 77.09, which was significantly higher compared with the 72.72 attained by NIEF group. In other words, compared with not providing IEF messages, providing IEF messages during game-based assessment was more beneficial for improving the effectiveness of

student knowledge acquisition during e-learning.

4.2 Evaluation of Enjoyment Perception

To evaluate learner's enjoyment perception toward the game-based assessment, descriptive statistics were used to analyze their scores on the enjoyment perception questionnaire, which used a 5-point Likert-type scale ranging from 1 (strongly disagree) to 5 (strongly agree). Table 1 shows the scores of the enjoyment perception questionnaire for the two groups of students. The average score for the four questions was 3.62; each question achieved a score exceeding 3, indicating positive student views regarding enjoyment of TRIS-Q-SP.

Table 1: The Mean Scores for the Enjoyment Questionnaire

Questions	NIEF	IEF	Total
I enjoyed playing the TRIS-Q-SP	3. 93	3. 79	3. 86
I enjoyed the competition while playing the TRIS-Q-SP	3. 75	3. 61	3. 68
I think this was an exciting game experience	3. 71	3. 55	3. 63
I would be happy to play similar games in the future when opportunities allow	3. 18	3. 41	3. 30
Total	3. 64	3. 51	3. 62

To explore whether different feedback types affected student enjoyment toward the game-based assessment, this study conducted the independent *t*-test by using feedback types as the independent variables and the enjoyment score as the dependent variable. The analysis of the independent *t*-test indicated that while the average enjoyment perception score (M = 3.64, SD =1.00) on NIEF group was higher than the one (M = 3.51, SD =. 81) on IEF group, there was no significant difference between the two groups (t=.541 , p=.591). The result suggests that providing immediate elaborated feedback during gameplay may not affect students' enjoyment perception when comparing it to the NIEF group.

5. Discussion

Based on Tsai's (2013) research, this study developed a tic-tac-toe-based formative assessment for single-player mode in an energy education e-learning system. Additionally, to investigate which types of feedback messages were appropriate for use in this game-based formative assessment and how distinct types of feedback messages affected e-learning effectiveness and learner perceptions, IEF and NIEF feedback mechanisms were designed and incorporated in TRIS-Q-SP game based on theories relevant to feedback types suitable for formative assessments.

The findings revealed that all participants improved their energy knowledge through the e-learning activity. The results of the dependent sample *t*-test indicated that regardless of the feedback type of TRIS-Q-SP game, the posttest scores for the energy knowledge test were higher than the pretest scores. Thus, the proposed online energy educational course that incorporated game-based formative assessment was effective in improving the energy knowledge for junior high school students. The result was consistent with previous researchers' findings (Wang, 2008; Tsai, 2013) indicating that game-based formative assessment can improve learning effectiveness.

This study also found that if the system provided immediate elaborated feedback during the TRIS-Q-SP game, it significantly increased the level of learner performance in energy knowledge. Based on one-way ANCOVA results, the participants who received immediate detailed feedback scored higher on the energy knowledge posttest than did those who received no IEF. The findings of the study were consistent with previous studies that suggested immediate feedback and elaborated feedback enhanced learning (Corbett & Anderson, 1989; Dihoff, Brosvic, Epstein, & Cook, 2003; Meyer et al., 2010; Van et al., 2011).

Furthermore, based on the average scores on the enjoyment scale, most students expressed positive perceptions toward the TRIS-Q-SP game, indicating that the game was popular among the students. Also, there was no significant difference between the two groups. The various opinions and comments that the students provided to open-ended questions suggested that most students thought the game was fun, leaving comments such as "I think the game is fun and exciting, but I wish there was more time," "I think this game is great! The game was different from what I imagined. To decide putting an O or X based on answering the questions correctly was very exciting," "Although I couldn't achieve high score list, I hope I can play such game in the future." Meanwhile, students' gameplay behaviors in TRIS-Q-SP also supports that this game was fun and enhanced the participation ratio for using online formative assessments. According to the game usage derived from system logs, in average the IEF and NIEF group played 210 and 182 tournaments respectively on TRIS-Q-SP during the experiment. The result was

consistent with previous researchers' findings (Wang, 2008; Tsai, 2013) indicating that game-based formative assessment can enhance learning motivation.

6. Conclusion and future work

In summary, the proposed TRIS-Q-SP, regardless of feedback type, facilitated e-learning effectiveness. The students expressed enjoyment and positive opinions. However, the various statistical results suggest that providing IEF for each question answered in the TRIS-Q-SP game was the optimal design. This design facilitated the enhancement of energy knowledge acquisition. Additionally, these feedback messages did not affect participant enjoyment. In the future, the TRIS-Q-SP can be compared with the TRIS-Q proposed by Tsai (2013) to investigate the learning effectiveness between single-player and multi-player assessment game. Also, future studies can employ the TRIS-Q-SP game in various e-learning courses to verify the effectiveness of the current study.

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