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An Investigation of Gender Differences in a Game-based Learning Environment with Different Game Modes

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ABSTRACT
This study aimed to explore the gender differences of participants' learning results, perceptions and gaming behaviors related to an energy quiz game with both single-player and multiplayer game modes simultaneously provided for participants. Seventy-four ninth-grade students played the game in six classes over three weeks. The pretest-posttest on energy knowledge and a survey on computer gaming attitude, competitive attitude and participation perception were also conducted in this study. The research findings indicated that although the female participants exhibited lower online gaming experience and a less positive gaming attitude than the male participants did before the experiment, all the participants had positive attitudes toward the quiz game, and the participants of both genders preferred the multiplayer game mode. However, the females had significantly better learning performance on energy knowledge acquisition than the males did after playing the game. More females than males were in favor of the single-player game mode according to the clustering analysis of students' gaming behaviors. After an in-depth analysis, this study found that their negative attitude toward computer games could be an important factor in explaining why more females than males preferred the single-player game mode, and why females performed better on learning performance than males did.
Keywords: gender differences, game-based learning, learning effectiveness, gaming behavior

INTRODUCTION

Since their introduction in the 1970s, computer/video games have become a prevalent recreational activity for young people (Boyle, Connolly, Hainey, & Boyle, 2012). Originally, these games were regarded solely as a form of after-school entertainment; however, they have recently garnered increased attention following the rapid development of computer and network technologies, and the recent revelations about their educational benefits. More and more scholars, such as Prensky (2001), have increasingly promoted digital games as an innovative form of learning activity for use in a formal learning environment. Digital game-based learning, which incorporates digital games in learning activities, has become a popular topic in educational technology research. Various educational games have been widely

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State of the literature

- Game-based learning has become a popular topic in educational technology research. Numerous studies have confirmed that it improves the learning results and motivation.
- Most studies have indicated that males and females differ considerably in their attitudes, preferences and participation behaviors regarding all types of pure digital games. Females are typically less active in playing digital games than are males.
- Most of the studies on game-based learning have focused on the overall learning results of learners. Few have explored the individual differences among learners. The gender differences are worth examining as digital games begin to be more widely used.

Contribution of this paper to the literature

- Few studies have investigated the gender differences of participants' preferences when both single-player and multiplayer game modes are simultaneously provided in an educational game for participants.
- This study found that females had significantly better learning performance on energy knowledge acquisition than males did after playing the energy quiz game. More females than males were in favor of the single-player game mode.
- This study found that a negative attitude toward the computer game could be an important factor in explaining why more females than males preferred the single-player game mode and why females performed better on learning performance than males did.

employed for educating students in different fields of study, such as mathematics, science, languages and social studies. Numerous studies have also confirmed that game-based learning improves the learning results and motivation of learners (Chen et al., 2012; Clark, Tanner-Smith, & May, 2013; Hou & Li, 2014; Hwang, Chiu, & Chen, 2015; Vos, van der Meijden, & Denessen, 2011).

Most past studies on game-based learning investigated the overall learning results; few focused on the individual differences among learners (Ke, 2008b; Papastergiou, 2009). Conversely, numerous studies on the digital games designed for pure entertainment have examined gender differences, and nearly all of them have addressed the substantial difference between males and females regarding their attitudes toward digital games. Most studies have indicated that males enjoy playing digital games more than females do (Chou & Tsai, 2007; Wright et al., 2001); males and females also differ in their gaming motivations. For example, males are more likely to play digital games for the challenge, competition, or interpersonal interactions than are females (Jansz, Avis, and Vosmeer, 2010; Olson, 2010). Additionally, the reports state that males and females thoroughly differ in their game content preferences. Females typically dislike competitive, violent, or 3D digital games (Lucas & Sherry, 2004), preferring logic and skill-training games (Quaiser-Pohl, Geiser, & Lehmann, 2006).

Following the evolution of technology in the recent decade, digital games have undergone a substantial transformation. Digital game markets, which were previously dominated by single-player games, have gradually been overtaken by online games of various genres (e.g., role-playing, action, sports, etc.) and platforms (e.g., computer, television and mobile devices) which enable players worldwide to participate using networks (most prevalently, the Internet). In other words, while players were limited to only competing against themselves or computer-controlled opponents in digital games in the past, they can now participate in digital games with unfamiliar people. Previous studies have reported that playing online games has now become the mainstream activity for internet users (Wei, Chen, Huang, & Bai, 2012; Weng et al., 2013). However, the participation behaviors of people of different gender in online games were observed to be similar to those in conventional single-player games: substantially more males than females play online games (Cole & Griffiths, 2007; Nagygyörgy et al., 2013; Williams, Yee, & Caplan, 2008). In other words, even when new forms of games arise, more males than females participate in them.

This situation implies that males and females differ considerably in their attitudes, preferences and participation behaviors regarding all types of pure digital games. Notably, females typically play digital games less often than males do. Therefore, the gender differences are worth examining as educational digital games begin to be widely used in formal learning activities at school. Although some studies have indicated that no substantial gender differences exist in regard to learning results in game-based learning environments (Ke & Grabowski, 2007; Papastergiou, 2009; Vos et al., 2011), most of these studies focused solely on the gender differences when participants partake in the educational games solely with the single-player game mode; few have explored gender differences in multiplayer educational games. Even few studies have investigated the gender differences of participants' preferences when both single-player and multiplayer game modes are simultaneously provided in an educational game for participants. Hence, this study aimed to explore the gender differences of learning performances and participation behaviors in a game-based learning environment with both single-player and multiplayer game modes.

Tsai, Tsai and Lin (2015) developed an educational game, TRIS-Q, which combines tic-tac-toe with multiple-choice questions related to energy education in an online learning environment. TRIS-Q was established in two versions: single-player and multiplayer game modes. Although Tsai et al. (2015) reported that no considerable difference existed between the single-player game players and the multiplayer game players in relation to their learning results and satisfaction levels, the participants were unable to freely select their own preferred game modes, and the gender differences in their analysis results were not explored. To clarify the gender differences in game-based learning results and behaviors, TRIS-Q was employed in the current study as the research instrument. In addition, the latest-developed multiplayer version by Tsai (2016) and the single-player version created by Tsai et al. (2015) were integrated and revised in such a way as to enable the students to freely select between them according to their own preferences. Thus, this study fully analyzed the gender differences among the students regarding their learning performances and gaming behaviors when both single-player and multiplayer game modes were simultaneously provided for them in an educational game.

Besides, in order to explore the possible factors leading to the gender differences related to their learning performances and gaming behaviors in this situation, this study also investigated participants' gaming characteristics (GCs) comprising their computer game attitudes, online gaming experience and competitive attitudes, prior to the experiment. In summary, the specific goals of this study are listed as follows:

(a) Compare the gender differences in GCs among participants.
(b) Compare the gender differences in learning results among students who participate in an educational game with single-player and multiplayer game modes.
(c) Compare the gender differences in gaming behaviors and perceptions among students who participate in an educational game with single-player and multiplayer game modes.
(d) Explore the factors that affect the gender differences related to their learning results and gaming behaviors in an educational game with single-player and multiplayer game modes.

METHODS

Participants

Seventy-four students (excluding those who were unable to fully participate in the experiment) from three ninth-grade classes in a high school in Kaohsiung City, Taiwan, were randomly selected as the participants of this study. Among these participants, 34 were male, and 40 were female. For the purpose of this study, none of the selected participants had received any energy-related education prior to the experiment.

Procedure

Before the experiment, all the participants completed the pretest on energy knowledge as well as the survey on their computer gaming and competitive attitudes. The experiment was conducted in correspondence with the schedules of the participants' living technology classes. All the participants partook in the experiment in six classes over 3 weeks (two classes each week; 45 min each class). At the beginning of the experiment, the teacher briefly instructed the participants to log onto the online learning system and play the TRIS-Q. Subsequently, the teacher requested the participants to complete their game-based learning activities at a rate of one learning topic each week. For each week, the teacher first asked the participants to read the energy learning materials for 20 min. After that, the participants could participate in the TRIS-Q and freely choose to play the single-player or the multiplayer modes of TRIS-Q based on their own preferences. Finally, after the game-based learning activities had ended, all the participants completed the posttest on their energy knowledge and the scales on their participation perceptions about the game-based learning activities.

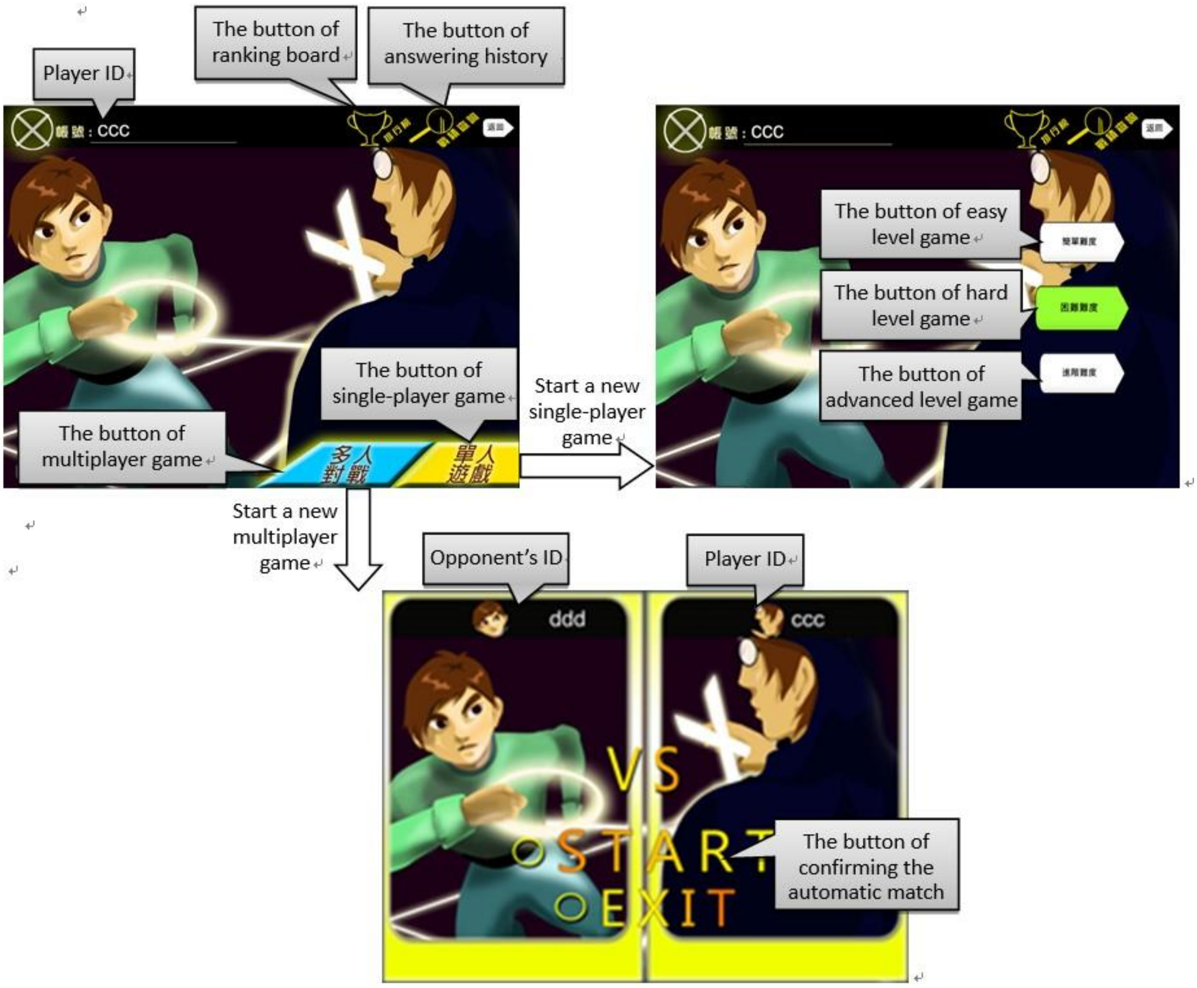

Figure 1. The process of starting a new game in TRIS-Q

Instruments

TRIS-Q

The multiplayer version of the TRIS-Q game developed by Tsai (2016) was integrated and revised with the single-player version of the game established by Tsai et al. (2015) to create a new game version in which players could freely choose the multiplayer mode or single-player mode for this study. This version was also integrated into the online learning system developed by Tsai et al. (2015), which could be accessed through a general web browser to access the energy education materials. The materials were divided into three topics: the sources of energy, the application of energy, and energy conservation and new energy. When a player accessed the game, the main menu screen appeared (left of Figure 1). The player could choose to begin the single-player game or the multiplayer game by clicking a corresponding button at the bottom right of the screen. When the single-player game was selected, three computer-controlled opponent difficulty levels (i.e. easy, hard and advanced) were provided

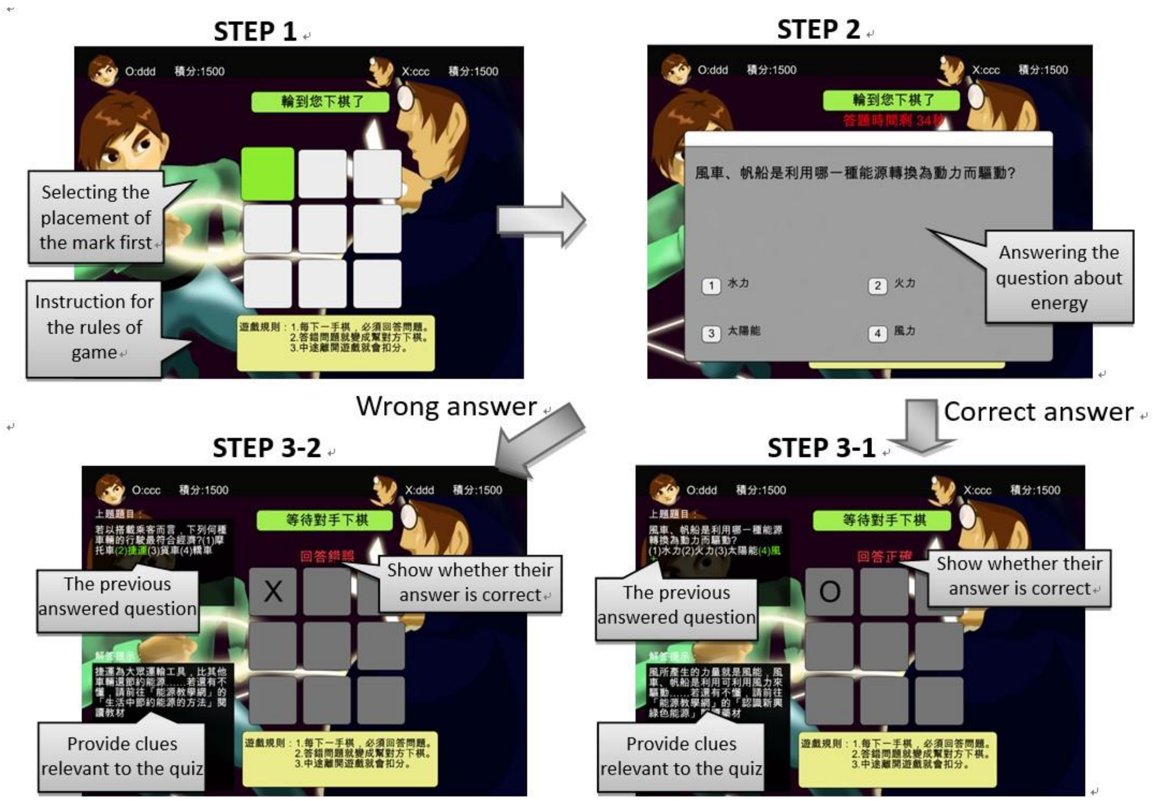

Figure 2. The process of taking a turn in TRIS-Q

for the player to choose from (right of **Figure 1**). When the multiplayer game was selected, the system randomly matched the player with an online opponent (bottom of **Figure 1**). After the difficulty level was selected (single-player mode), or after the matching was completed and both the players had pressed the start button (multiplayer mode), the competitive quiz game began.

When the game began, a tic-tac-toe board appeared on the screen (step 1 of **Figure 2**), which the players used to play the game. The basic rules of the game were the same as those of a typical tic-tac-toe game, in which the player who succeeds in placing three of his or her marks in a row wins. However, whenever a mark was placed on the board, a random multiple-choice question about energy knowledge appeared (step 2 of **Figure 2**). Answering the question correctly enabled a player to place her or his own mark on the selected grid (step 3-1 of **Figure 2**), while answering it incorrectly caused the opponent's mark to be placed instead (step 3-2 of **Figure 2**). In addition, when completing a turn and waiting for their opponent's turn, the left side of the game screen will provide the previous question and feedback to offer learning clues relevant to the question for the player (step 3-1, 3-2 of **Figure 2**). Additionally, as shown in **Figure 1**, a ranking board and a personal answering history are provided in the TRIS-Q game. The ranking board lists the 10 players with the best game scores and the 10 players with the highest rates of correct answers. The personal answering history lists all the test questions attempted by players and their corresponding answers.

Energy Knowledge Test

A self-developed energy knowledge test was applied to clarify the changes in the learning results of the students after their participation in the TRIS-Q game. The questions were based on the energy knowledge content tested in the quiz games. A total of 25 multiple-choice questions were prepared for a total score of 100 points (e.g., "What is the source of energy for the Earth?"). Two middle school teachers examined the questions to verify their validity. According to the pre-examination study results from 58 ninth-grade students, the Kuder–Richardson reliability of the questions was .84, the average difficulty level of the questions was .65 and the average level of discrimination was .51.

Computer Game Attitude Scale

The New Computer Game Attitude Scale developed by Liu, Lee and Chen (2013) was incorporated to clarify the computer gaming attitudes of the participants before the experiment. The 22 questions in the scale were divided into three subscales: cognition, affection and behavior. The cognition subscale was designed to clarify whether the participants felt that computer games enhanced their learning results and whether they were confident about playing computer games (e.g., "Playing computer games increases my typing speed"; "Playing computer games is easy for me"). The affection subscale indicated the level of passion of the participants for computer games (e.g., "I am very interested in solving problems in computer games"). The behavior subscale revealed the influence of the students' participation in computer gaming on their free time (e.g., "Playing computer games is part of my life"). While the original scale was measured using a 4-point Likert scale, in this study, the scale was modified into a 5-point Likert scale. The overall Cronbach's α value of the modified scale was .93. Four additional questions (i.e. "Do you have a computer in your home?" "How much time do you spend on using computers at home each week?" "How much time do you play computer games each week?" "Have you ever played online games?") were added to the scale to clarify the participants' computer gaming behaviors in their free time.

Competitive Attitude Scale

The subscale on the enjoyment of competition in the Competitiveness Index (Harris & Houston, 2010) was used as the competitive attitude scale in this study to clarify the competitive attitudes of the participants before the experiment. The scale used a 5-point Likert scale and comprised nine questions (e.g., "I enjoy competition"; "I feel satisfied when competing with others"; "I am afraid of competing with others"). Cronbach's α of the scale was .93; the test–retest reliability was .85.

Participation Perception Scale

A self-developed participation perception scale was used to clarify the feelings of the participants regarding their TRIS-Q participation. The scale was based on the enjoyment scale formulated by Downs and Sundar (2011) and featured a 5-point Likert scale. The scale comprised 14 questions (e.g., “I like this learning method because it involves playing and testing”; ”This gaming method motivates me to earnestly learn about energy”; “I feel that this game enhances my learning”; “I enjoy playing this tic-tac-toe quiz game”; “I was ecstatic when playing the tic-tac-toe quiz game”; and “I enjoy the competition in the tic-tac-toe quiz game”). Cronbach α of this scale was .95.

RESULTS

Analysis of gender differences in GCs

By using the scale survey before the experiment, the gaming experience, computer gaming attitudes and competitive attitudes of the participants were clarified. According to the gaming experience survey results on the computer game attitude scale, 98.6% of the participants owned a computer in their home, but most of the participants used their computers (85.1%) and played computer games (91.9%) no more than 10 hours each week, and only 23% of the participants had the experience of playing online games. This indicated that the participants did not use computers to play computer games frequently in their free time. However, according to the further analysis on the online gaming experience of the participants of different genders, 67.5% of the females had no online gaming experience, whereas 88.2% of the males did. The Pearson chi-square test results, $\chi^2 (1) = 4.47$, $p < .05$, revealed a significant difference between the males and females for the ratios of their online gaming experience, with the online gaming experience of the males being significantly higher than that of the females.

The answers for the computer game attitude scale were summarized as scores. According to the statistical results, the participants scored an average of 3.40 points for their computer gaming attitudes, indicating that most of the participants exhibited positive computer gaming attitudes. Regarding any gender differences in participant computer gaming attitudes, the average scores of the males and females were 3.64 and 3.20, respectively. The *t*-test results, $t(60) = 2.826$, $p < .05$ indicated that the participants of different genders exhibited significant difference between their computer gaming attitudes, with the gaming attitudes of the males being significantly more positive than those of the females.

The responses on the competitive attitude scale were also statistically summarized as scores. According to the statistical results, the overall average score for the competitive attitudes of the participants was 3.42, indicating that most of the participants exhibited positive competitive attitudes. Regarding any gender differences about the participants’ competitive attitudes, the males exhibited a higher average score (3.58) than that of the females (3.29). However, on the basis of the *t*-test results, in which $t(72) = 1.914$, $p > .05$, the gender difference in competitive attitudes was not significant.

Table 1. Comparison of gaming behaviors and participation perceptions

	Single-player games (average times)	Multiplayer games (average times)	Answered questions (average times)	Participation perceptions (average scores)
Males	36	54	295	4.08
Females	43	53	323	4.11
Total	40	54	310	4.09

Analysis of the gender differences in game-based learning results

The average pretest score of the participants on their energy knowledge before the game-based learning activity started was 56.59 (N = 74, SD = 15.18); the average posttest score of the participants on their energy knowledge after the game-based learning activity ended was 72.49 (N = 74, SD = 19.40). The paired sample t-test results, $t(73) = 8.927$, $p < .000$, revealed that the posttest scores were significantly higher than the pretest scores. In other words, after the participants participated in the game-based learning activity, their knowledge of energy improved significantly.

To clarify the gender difference in the game-based learning results, an analysis of covariance (ANCOVA) was performed. The gender variable was treated as the independent variable, the pretest scores on energy knowledge as the covariate variable and the posttest scores as the dependent variable. Before undertaking ANCOVA, the assumption of homogeneity of regression was tested (F (1, 70) = .74, p > .05) and was not violated. The one-way ANCOVA results, in which F (1, 71) = 4.350, $p < .05$ and $\eta^2 = .058$, were statistically significant, indicating that the gender difference in the game-based learning results of the participants on energy knowledge was significant when the effect of the covariance was controlled. For the *post hoc* comparison results regarding the adjusted average scores, the average posttest score of the females was 75.82, which was significantly higher than that of the males (68.57). In other words, the females exhibited more satisfactory game-based learning results than the males did.

Analysis of the gender differences in gaming behaviors and perceptions

The game records were used to statistically analyze the gaming behaviors of the participants. **Table 1** lists the average numbers of times the participants participated in the single-player and multiplayer games, and answered the questions about energy knowledge in the games, listed by gender. Additionally, **Table 1** displays the participants' average scores on the participation perception scale, also by gender. According to the statistical results, as listed in **Table 1**, the average number of times the participants participated in the multiplayer game was higher than the average number of times they participated in the single-player game. Within the period of the experiment, each participant played the TRIS-Q game for an average of 94 times. The participants scored an average of 4.09 points for their feelings toward the game after the experiment, indicating that their participation behaviors and feelings were considerably positive.

Table 2. Clusters of participants' preferences of the TRIS-Q game modes

	Group 1: Preferred single-player game (number of people)	Group 2: Preferred multiplayer game (number of people)	Group 3: Preferred both single-player and multiplayer games (number of people)
Males	4	23	7
Females	11	27	2
Total	15	50	9

Regarding any potential gender differences in the statistical results, as shown in **Table 1**, the apparent gender differences were regarding the number of single-player games participated in and the number of questions answered; those of the females were all higher than those of the males. In addition, no apparent gender differences were observed regarding the number of times the participants participated in the multiplayer game and the scores on the participation perceptions of the participants. However, according to the *t*-test results, no significant gender differences were identified regarding the number of single-player games participated in ($t(72) = .474$, $p > .05$), the number of multiplayer games participated in ($t(72) = .079$, $p > .05$), the number of questions answered ($t(72) = .521$, $p > .05$) and the participation perceptions ($t(72) = .306$, $p > .05$).

Besides, the participants were grouped using the hierarchical clustering method based on their preferences, which were determined by the number of times each participant partook in the single-player and multiplayer games in the experiment. As shown in **Table 2**, the participants were divided into three groups: those that preferred the single-player game (15 participants), those that preferred the multiplayer game (50 participants) and those that enjoyed both the single-player and multiplayer games (9 participants). According to the clustering results, most of the participants (67.6%) preferred the multiplayer game. Regarding any potential gender differences, the group that preferred the multiplayer game constituted a majority of both the males and females at nearly equal ratios, 67.7% and 67.5%, respectively. The ratio of the females who preferred the single-player game ($N = 11$, 27.5%) was higher than that of the males who preferred the single-player game ($N = 4$, 11.8%). Conversely, the ratio of the males who enjoyed both the single-player and multiplayer games ($N = 7$, 20.6%) was higher than that of the females who enjoyed both the single-player and multiplayer games ($N = 2$, 5%). Accordingly, whereas a majority of both the males and females preferred the multiplayer mode of the TRIS-Q game, more females preferred the single-player mode.

Analysis of the factors that affected the gender differences in learning results and gaming behaviors

As revealed in the preliminary analysis, the game-based learning results of the females were more satisfactory than those of the males. For the preference of the game modes, more females than males preferred the single-player mode. Therefore, the factors that might have affected the game-based learning results and behaviors of the participants of different genders

Table 3. Correlation matrix for the research variables regarding the participants

Variable	1	2	3	4	5	6
1. Energy knowledge posttest score	1.00					
2. Computer game attitude	-.233*	1.00				
3. Competitive attitude	.090	.153	1.00			
4. Number of games participated in	.338**	-.149	.194	1.00		
5. Number of questions answered	.397**	-.174	.195	.988**	1.00	
6. Participation perceptions	.051	.048	.309**	.205	.203	1.00

*p<0.05 **p<0.01

were further analyzed. First, the factors that enabled the females to acquire more energy knowledge than the males did in the experiment were explored. **Table 3** illustrates the analysis of the correlation between the posttest scores of the participants and their GCs and gaming behaviors. The results reveal that the learning results of the participants were significantly positively correlated to the numbers of games they participated in (r=.338, p<.01) and questions they answered (r=.397, p<.01), indicating that the more frequently a participant partook in the games and answered the questions, the better the participant's learning result was. This supported the view that the game can enhance the participants' knowledge acquisition if the participants can partake in this game more frequently. This also supported the possible reason why the females acquired more energy knowledge than the males did in the experiment. As displayed in **Table 1**, the females partook in more games and answered more questions than the males did; thus, the finding that the learning results of the females were better than those of the males is reasonable. In other words, because frequent participation in the games increased the learning opportunities for the females, the females substantially outperformed the males in the game-based learning experiment.

Secondly, in order to identify the factors that caused the females to prefer the single-player mode more than the males did, the 11 females clustered into the group preferring the single-player mode were further analyzed. **Table 4** depicts the comparisons among the 11 females, the males who preferred the multiplayer mode, and all the participants, regarding their GCs, gaming behaviors and learning results. It revealed that the average scores of the competitive attitudes and participation perceptions of the females who preferred the single-player mode did not apparently differ from those of all the participants or those of the males who preferred the multiplayer mode. They differed primarily regarding their gaming attitudes, the number of games participated in, the number of questions answered and the posttest scores. The gaming attitude scores of the females who preferred the single-player mode were apparently lower than those of all the participants and those of the males who preferred the multiplayer mode. The t-test result ($t(32) = 2.149$, $p = .039 < .05$) further confirmed a significant difference between the females who preferred the single-player mode and the males who preferred the multiplayer mode, regarding their gaming attitude scores. Conversely, the average number of games (130) participated in by the females who preferred the single-player mode was apparently larger than that of all the participants (94). The number

Table 4. Comparison data on the GCs, gaming behaviors and learning results of the females who preferred the single-player mode

	Competitive attitude	Gaming attitude	Participatory feeling	Numbers of games participated in (Total, single-player, Multiplayer)	Number of questions answered	Posttest score
Female participants that preferred the single-player mode (*N* = 11)	3.56	3.06	3.88	130,116,14	441	77.82
Male participants that preferred the multiplayer mode (*N* = 23)	3.62	3.59	3.92	69, 80, 61	220	67.48
All the participants (*N* = 74)	3.42	3.40	4.09	94,40,54	310	72.49

of questions answered (441) by the females who preferred the single-player mode was also apparently larger than that of all the participants (310) and that of the participants who preferred the multiplayer mode (220). Consequently, the average posttest score of the females who preferred the single-player mode was higher than that of all the participants and that of the participants who preferred the multiplayer mode. This finding again verified that the number of games participated in and questions answered were positively correlated to learning results; this also supported the analysis results from the data provided in **Table 3**, namely, that the gaming attitude scores were significantly negatively correlated with the posttest scores.

The competitive attitudes and participation perceptions of the females who preferred the single-player mode did not apparently differ from those of the general participants, and six of these 11 females (55%) had ever played online games before. However, the females who preferred the single-player mode exhibited a lower average score for their gaming attitudes than did all the participants and all the females in this study (M = 3.20). Statistically, this average score was also significantly lower than that of the participants who preferred the multiplayer mode. Therefore, the possible reason why these 11 females preferred the single-player mode is due to the low degree of their gaming attitude. Moreover, according to the analysis outlined in the section on the participants' GCs analysis, the females scored significantly lower than the males did in regard to their gaming attitudes. In summary, the possible reason why more females than males preferred the single-player mode in this study is that the gaming attitude scores of the females were lower than those of the males.

DISCUSSION

In order to explore the gender differences when students simultaneously played an educational quiz game with single-player and multiplayer modes, 74 ninth-grade students participated in this study. Before the experiment began, the GCs of these students, comprising their gaming experience, gaming attitudes and competitive attitudes were examined, and the students partook in a pretest on their energy knowledge. During the experiment, the students voluntarily chose to participate in the single-player or multiplayer mode's TRIS-Q to learn the required energy knowledge through the games. After the experiment, the students partook in a posttest on their energy knowledge and a survey on their participation perceptions. Finally, an in-depth analysis was conducted on the survey data and the gaming behaviors of the students.

The research findings indicated a significant gender difference in the online gaming experience of the participants before the experiment. The males possessed substantially higher online gaming experience than did the female participants; only 32.5% of the females had ever played online games before. This implied that the females had not followed the current trend in which online games had become the mainstream digital games; this also showed a lack of interest in digital games on the part of the females. This was consistent with previous survey results on pure digital games, in which males were found to enjoy digital game activities more than the females did (Bonanno & Kommers, 2008; Chou & Tsai, 2007). Furthermore, the females scored significantly lower than the males did on the computer game attitude scale, revealing that the females were considerably less positive in their attitudes toward digital games than were the male participants. This also implied that males enjoyed digital games more than females did and was consistent with the findings of previous studies, which have indicated that male students held more positive attitudes toward digital games than female students did (Bonanno & Kommers, 2008; Chou & Tsai, 2007; Liu et al., 2013). Besides, although the average score of the males was higher than that of the females in relation to their competitive attitudes, the difference was not statistically significant. This result differed from the findings of some previous studies, in which males were found to be considerably more positive than females regarding competition (Helmreich, Sawin, & Carsrud, 1986; Gill, 1988; Lynn, 1993). However, this also supported that no consistent argument has been agreed upon regarding any potential gender differences in competitive attitudes, because some studies also have reported that females are more competitive than males are (Harris & Houston, 2010; Houston, Carter, & Smither, 1997); others have indicated that no significant gender differences exist for competitive attitudes, which is consistent with the findings of this study (Yeoh & Yeoh, 2015).

Although the females exhibited lower online gaming experience and gaming attitude scores than the males did before the experiment, the females were considerably active in the multiplayer TRIS-Q game during the experiment; the average number of multiplayer games the females participated in was only lower than that of the males by 1. The average number of single-player games the females participated in was higher than that of the males by 7, and the females scored higher than the males did on their participation perceptions. Ultimately, the learning results of the females were substantially better than those of the males.

The research findings on the overall learning results implied that the TRIS-Q game is effective in promoting knowledge acquisition because participants' posttest scores on energy knowledge were significantly higher than their pretest scores. This result was consistent with the findings by Tsai et al. (2015), in which the TRIS-Q game was found to strengthen the students' learning results. This was also consistent with the arguments in previous studies that game-based learning enhances learning effectiveness (Vogel et al., 2006). On the other hand, the experiment results regarding the gender differences in the learning results differed from the findings of some previous studies which claimed that there were no gender differences in game-based learning results (Annetta, et al., 2009; Ke, 2008a; Vogel et al., 2006); this study found that the females significantly outperformed the males on learning results. However, most previous studies employed one game mode in their experiments, while this study incorporated two game modes, allowing the participants to freely choose. This implied that the females might exhibit more favorable learning outcomes than the males when two or more different game modes are provided to the participants.

The research findings on the participation perceptions of the participants implied that the game design encouraged both the males and females to participate. Within the short duration of the experiment, both the males and females frequently participated in the TRIS-Q competitions, and they both scored considerably well on their participation perceptions. This was consistent with the findings in most previous studies, in which game-based learning enhanced the motivations of learners to participate in learning activities (Hwang et al., 2015; Vogel et al., 2006); no gender differences were observed regarding the psychological flow of the educational game participants (Hou & Li, 2014).

For the game mode preferences of the participants, both the males and females participated in the multiplayer game more frequently than in the single-player game; the average number of multiplayer games the males participated in was nearly equal to that of the female participants. Moreover, according to the hierarchical clustering results based on the gaming behaviors of the participants, 67.7% of them preferred the multiplayer game. Because few previous studies have investigated students' preference between single-player and multiplayer educational games, comparing the results of this study with those of previous studies is difficult. However, the results were consistent with the current trend of digital game development, in which online games are the mainstream form of digital games for young people. The results were also consistent with the previous findings that people are more motivated to play digital games when they compete with human opponents (Lim & Reeves, 2010; Mandryk, Inpken & Calvert, 2006). The findings implied that the females' fondness for multiplayer online games in formal learning activities was nearly equal to that of the males, even though the females lacked online gaming experience, and past studies indicated that in their free time, males seem to enjoy online game activities more than females do (Cole & Griffiths, 2007; Nagygyörgy et al., 2013; Williams, Yee, & Caplan, 2008).

However, the average numbers of questions answered and single-player games the females participated in were higher than those of the males. When these results are considered along with the finding that the females outperformed the males in their learning results, it reveals that the females surpassed the males in their game-based learning behaviors and results. To explore the factors leading to this finding, the various data on the participants were analyzed. Firstly, the results indicated that the numbers of games the subjects participated in and the amount of questions answered were significantly positively correlated with the participant's posttest score on energy knowledge. This reasonably explains the superiority of the females over the males in their learning results because the females participated in more games on average and answered more questions than the males did. Secondly, to explore the factors why the females participated in more single-player games on average, an in-depth analysis was conducted on the 11 females who preferred the single-player game. The analysis revealed that the average numbers of all games they participated in and the questions they answered were higher than those of all the participants. Moreover, the average posttest score of these females was substantially higher than that of all the participants. This finding indicated that the more frequently a participant participated in a single-player game and the more questions the participant answered in the game, the more satisfactory the learning result of the participant. Because the single-player mode did not require a player to wait to be matched with an opponent, it is reasonable that the participants who persistently preferred the single-player mode participated in more games than did those who participated in the multiplayer games. Additionally, these participants differed the most from the males who preferred the multiplayer mode, regarding their gaming attitude scores, which were significantly lower than those of the males who preferred the multiplayer mode. In other words, a possible reason why more females than males preferred and participated in single-player games is that most females were less positive toward computer games.

In summary, because the gaming attitude scores of more females were relatively low, more females chose to participate in single-player games than did males. Also, because single-player games progress faster than multiplayer games, the overall average numbers of games participated in and questions answered by the females were higher than those of the males; thus, the females outperformed the males on the game-based learning results. These were the critical reasons why the game-based learning behaviors and results of the females were more satisfactory than those of the males.

CONCLUSION AND FUTURE WORK

This study investigated the gender differences in game-based learning behaviors and results when choosing and using an educational quiz game with single-player and multiplayer game modes. The results confirmed that gender differences existed regarding digital gaming attitudes and online gaming experience of the participants before the experiment began. However, when the digital game was incorporated in the formal learning activity, the females did not differ significantly from the males regarding their participation behaviors and perceptions. Conversely, the females participated in substantially more games and learned more energy knowledge than did the males. Further analysis revealed that the previous gaming attitudes of the females could have substantially influenced their game-based learning behaviors. Because the gaming attitude scores of the females were generally lower than those of the males, more females than males preferred the single-player mode. Consequently, the the females participated in more games than the males did, and outperformed the males regarding their learning results. In other words, it implied that worrying about gender differences is unnecessary when digital games are applied in a formal learning environment. On the contrary, providing more gaming modes for students is needed. Although this study proved that the multiplayer game mode was preferred by the participants of both genders, it also proved that female students may outperform male students in their game-based learning results when more types of games are available for students to freely choose between.

Although the results of this study are applicable for various game-based learning activities, some research limitations, due to the research method or data, need to be improved in the future. For example, control groups or more strict experiment designs are required to verify some results of this study because the research validity may be influenced by the one-group pretest-posttest design. More samples and more student characteristics pertaining to gaming and learning are also required to gather and further verify some results of this study because many factors may affect the gender differences in the gaming behaviors and learning results of students.

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