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# Effects of Game-Based Instruction on the Results of Primary School Children Taking a Natural Science Course

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**Abstract:** This study explored the effects of scenario simulation games and e-textbooks on the learning outcomes of elementary school students. The study subjects were 60 primary school students classified into two groups: The experimental group was provided with scenario simulation course materials, and the control group received e-textbook materials. The learning outcomes were compared between the two groups, which were further divided by ability level and gender. The female subjects in the experimental group showed slightly less improvement than the experimental group males, who showed significantly greater improvement than the female control group subjects. Use of the e-textbook had a less positive effect on learning outcomes than the scenario simulation game-based instruction.

**Keywords:** e-textbook; game-based instruction; gender; scenario simulation

## 1. Introduction

### *1.1. Background and Motive*

Curricula in Taiwanese elementary schools generally require conventional paper textbooks, although some teachers use e-textbooks as teaching aids. Numerous studies and on-site observations by teachers have indicated moderate overall effects of text- and image-based teaching on the learning outcomes of most students in regular classes. However, a small number of students comprehend text slowly, sometimes showing little interest in textbook learning, lacking any learning intention, or even actively resisting learning. It is clear that text-based teaching does not always result in mastery of course content. In contrast, the researchers of Taiwan ministry of education and primary school teachers who have reported that slower learners concentrate better when teaching is delivered via videos (VCR) and computer games. Appropriate game-based instruction could thus help students to comprehend traditionally textbook-based content [1].

In this study, students attending e-textbook courses provided by an elementary school were designated as the control group. The use of e-textbooks is reshaping students' reading and learning styles; students are increasingly using e-texts for knowledge acquisition [2]. An e-textbook is generally defined as an electronic or digital version of a printed textbook [3]. The use of digital learning materials is increasing in the classroom setting, as reported by frontline teachers. Such e-textbooks are typically available in the following forms: (1) A video edition of a textbook, (2) an instructional supplement (in the form of videos or animations), and (3) game-based interactive practice materials (integrating different types of multimedia animations, games, and test materials) [4].

Game-based interactive practice materials include shooting, matching, sports, and riddle-solving paradigms. However, such materials may be only partially relevant to the courses into which they are incorporated. Though schoolchildren may derive enjoyment from these materials while completing comprehension exercises, their test results on the topics addressed by the materials do not tend to drastically improve. While interviews with schoolteachers have shown that the use of e-textbooks can substantially improve students' interest in learning, measuring learning outcomes requires rigorous experimental design [4]. This study developed a set of game-based units that were strongly related to the topics taught in schools. These materials constituted digital learning resources that enabled students to learn via scenario simulation environments. The learning outcomes of students performing exercises based on these materials were compared with those of students performing exercises from e-textbooks.

Game-based instruction is a tool that comprises audiovisual features, animations, videos, and games, as well as enabling interactive learning [4]. In Taiwan, the majority of elementary education textbooks are published by local private-sector publishers [5]. In the digital information age, digital games are central to the lives of children and adolescents [6]. Digital game-based instruction has received greater academic attention of late because it can encourage learner engagement which traditional forms of digital learning are typically less able to do [7,8]. In addition, many students demonstrate a strong preference for playing digital games; such games can constitute fun and diverse learning experiences. Due to the high interest level of students in learning-based games and their ability to play them, they can concentrate for longer periods of time than is possible in a standard, textbook-based classroom setting. This enables students to acquire concepts quickly and increases their willingness to engage in active learning [9–11]. In learning-based games, text is simplified, and the course contents are presented via simulations. After teachers explain the tasks, the students play the learning-based games autonomously to acquire course content. Completing levels within the games gives the player a sense of accomplishment, enhances their interest in learning, and avoids the stress caused by the need to read large amounts of text in paper textbooks.

Game-based instruction appeals more strongly to schoolboys than schoolgirls; this was illustrated by the findings of Kron et al. [12], who showed that male students had higher levels of knowledge regarding computers and games. Nevertheless, the rate of gaming among female students has increased. This growing trend was illustrated by a survey conducted by the NPD group, a market research company reporting that the percentage of women in the United States who played games increased from 23% in 2008 to 28% in 2009. Kron et al. [12] incorporated scenario simulation games into medical education programs and determined that female students showed more interest in simulation-based instruction than did their male counterparts; furthermore, the females pragmatically sought to reproduce their sensory experiences from gameplay, which was characterized as being joyful; this helped them to develop certain skills, enhanced their interactions with patients, facilitated their understanding of human anatomy, enabled them to mentally prepare for similar real-world experiences, and aided them in reflecting the lecturers' opinions and teaching contents. These authors' findings also showed that more female than male subjects chose to play scenario-driven puzzle and role-playing games. Therefore, following Kron et al. [12], the present study examined gender differences in learning outcomes in digital game-based instruction.

### *1.2. Research Purpose*

This study employed game-based instruction featuring scenario simulations in which the content corresponded to a fifth-grade science course unit, namely the "Carbon Reduction and Carbon Footprint" unit. Text was converted into interactive media. Specifically, the unit contents were explained through voice-overs, and the text content of the paper textbook was converted into pictures and integrated into educational games, thus enabling students to become fully immersed in an interactive learning environment featuring stimulating images and sounds. We then compared the learning processes involved in different types of game-based instruction to determine which materials were most preferred by the students. Then, the students' learning outcomes in response to the game-based instruction and e-textbook were assessed, with the results serving as a reference point for teachers designing teaching content and deciding what proportion of such materials should be incorporated into the classroom.

This study investigated whether the use of a game-based approach that was highly relevant to course subject matter would enable schoolchildren to achieve similar or better learning outcomes versus conventional e-textbooks. The overall learning outcomes, average grades in different semesters, and gender differences in learning outcomes were examined in the context of game-based instruction.

## 2. Literature Review

### *2.1. Incorporation of Scenario Simulation into Game-Based Instruction*

The game-based units featured simulated scenarios that would be difficult or impossible to emulate in the real world and were designed to provide the students with comprehensive knowledge of the subject matter. Scenario-driven simulation enables effective learning by creating a lifelike, safe environment in which learners can cultivate their skills [13]. To facilitate the application of knowledge acquired by students to real-life contexts, typical game-based instruction integrated with scenario simulations comprises not only virtual scenarios but also the guidance and feedback mechanisms necessary for achieving desired learning outcomes [14,15]. The materials are presented in a combination of multimedia formats (e.g., video, audio, and images) to construct virtual environments stimulating real-life scenarios [16].

The content of our game-based course unit was developed according to the principles of Hsieh [17], i.e., providing stimulating, thematic, and story-driven scenarios that improve learning motivation, knowledge, and systematic and strategic planning in alignment with the teaching objectives; they also provide matching activities that facilitate knowledge acquisition, present various decision-making tasks requiring learners to provide different answers, present real images on the user interface to expedite learners' preparation for virtual learning, provide navigational aids on the user interface to ensure ease of operation, and provide role-playing games to immerse learners in the virtual learning environment.

These design principles for digital game-based instruction correspond with the scenario simulation, game-based digital learning model proposed by Garris et al. [18]. This learning model was constructed by integrating teaching content and game features to develop an educational program that triggers a learning cycle of user judgment and reaction. In addition, this model involves feedback that ensures enjoyment and engages students in the learning process to help them achieve training objectives or specific learning outcomes [19]. The design underpinning this game-based instruction is similar to that proposed by Garris et al. [18], who describe the aims of digital game-based instruction in detail. First, an educational game integrating teaching content with gameplay is designed. Second, the game enables players to become immersed in problem-solving and the execution of various actions, with systematic feedback provided. In summary, digital gameplay provides a relaxing and engaging learning environment [20] that aids learners in developing basic skills and knowledge of particular subject-matter.

### *2.2. Game-Based Digital Learning: Effect of Gender*

The learning achieved through game-based instruction is critical to any discussion of the value of this paradigm. Some researchers from the Taiwan ministry of education have determined that games are critical for engaging and motivating learners. The proposed reasons why students find online digital games engaging include the joyful, engaging, and motivational experiences that arise from immersion in games due to three main factors: First, games have a relatively high degree of complexity, with students beginning at the easiest level and progressing to higher levels according to a set sequence; specifically, students receive feedback as they progress through the game levels, which provides instant satisfaction. Second, games are challenging, and students can acquire game-playing tips by reading game guides or through trial and error, which satisfies their sense of adventure and their curiosity.

Third, games are entertaining and fun, new knowledge can be acquired though gameplay, and students experience a greater sense of accomplishment from the game world than from the real world [21,22].

Rosas et al. [23] reviewed studies on digital games and reported that game-based instruction confers substantial benefits to learners in four respects: Learning achievement, development of cognitive competence, learning motivation, and learning engagement. Via game-based instruction, student competency can be enhanced. For example, students' cognitive and spatial competence was enhanced when they played a specially designed educational game. Researchers who support game-based instruction note that a game can provide a rich environment in the context of game-based instruction, can serve as a powerful medium for improving motivation, and can enhance students' cognitive competence, spatial competence, and creativity. Accordingly, digital games can be used to create effective learning environments [24].

Liu et al. [25] observed that when an immersive experience characterizes the learning stage, the challenging nature and feedback mechanisms of digital games can elicit motivation from demotivated learners or reduce their learning anxiety, encouraging them to identify solutions through trial and error or imitation. The educational relevance of such games has been widely studied [6,26]. Sardone and Devlin-Scherer [27] investigated how digital games improve the learning outcomes of children aged between 6 and 12 years; the children reported that the games encouraged them to learn about difficult subjects, provided an interesting perspective on problem-solving, facilitated learning, and strengthened their interest in the subject matter. Several studies have also asserted that game-based instruction promotes learning interest and motivation [9,10,28,29]. These studies indicate that applying digital games, which employ gameplay and feedback to engage players, to educational practices can contribute to student learning [30]. Numerous video- and app-based games have entered the market since 2013, leading to a linear growth in the number of female game players worldwide [31]. According to Kron et al. [12], who incorporated scenario simulation games into medical education, the majority of the students enrolled in their study preferred to acquire medical knowledge through game-based simulations (98%), stated that new media technologies should be better utilized in medical education (95%) and believed that the educational relevance of videogames could be improved (80%). Furthermore, 39% of their female subjects believed that videogames had potential educational value, compared with only 31% of male subjects.

There remain many criticisms of game-based digital learning, such as that they have the potential to cause addiction, violence, and other negative effects [32]. In addition, many studies have also found that the effectiveness of game-based digital learning varies, unlike traditional teaching or digital learning; thus, the results of game-based learning can be uncertain.

### 2.3. Research Questions

(1) Will the experimental group (who used scenario simulation game-based instruction) and the control group (who used an official e-textbook) show a superior learning outcome (improved knowledge)?

(2) After the implementation of the scenario simulation game-based instruction, will students with low semester grades (i.e., 60–79 points) achieve significantly improved learning outcomes?

(3) After implementation of the scenario simulation game-based instruction, which gender will achieve better learning outcomes, and will any difference be significant?

## 3. Research Method

### 3.1. Adjusting the Content of the Game-Based Instruction

We collaborated with teachers before developing our game-based instruction. By applying their advice, we designed the game-based instruction (Figure 1), developed the levels of the games (Figures 2–4), implemented relevant material, and collected data. First, the teachers ascertained the paper-based learning content that the students considered most interesting and most difficult. We consulted this information to adjust the content of the game-based instruction that appeared on the screen to make it more easily understandable.


**Figure 1.** Homepage of the game-based instruction on the topic of carbon footprint.


**Figure 2.** Game map (illustrated using cinema 4D and MAYA).


**Figure 3.** Game levels of a learning unit.


**Figure 4.** Calculation of total carbon emissions after the game is finished.

### 3.2. Participants

(1) The participants were fifth graders aged between 10 and 11 years and recruited from an elementary school in Taoyuan, Taiwan. Students from two regular classes were recruited, with one class of 30 students (14 female and 16 male students) being designated as the experimental group. The students' knowledge and learning comprehension were assessed overall and at the group level. Lin and Lin [31] stated that the purpose of classifying students into two groups is to gain an in-depth understanding of learning outcomes; with the selecting conditions of experimenting classes, we chose two classes that had relative similarities in the average GPA of last semester, numbers of each class, the ratio of male and female students, and the range of ages. As for the individual scores for both two classes, the average score division was comparatively even, which showed no extremely high or low grades scored in each class. Therefore, the error for the experiment would be kept to the minimum. In addition, the time that students spend on the smart phones or computer games was evaluated in selection conditions. For both two experimenting classes, students would spend at least around one hour on their phones and computers, which includes the time for using computers in their classes per day. All the above selecting conditions are based on the most common situations for elementary students. Thus, our participants were further put into the following groups to analyze the learning outcomes of the game-based instruction:

1. Experimental and control group: Using game-based instruction and an e-textbook, respectively.
2. Score groups (60–79 and 80–100): Some students comprehend text more slowly, so to better understand the learning improvement rate of the groups receiving different sets of learning materials, the students were classified according to their pre-test scores. The pre-test cutoff score for grouping was determined after discussions with teachers. Semester scores over the previous 3 years were averaged; typically, the semester score of a fifth grader is between 80 and 95. Among the few students with an average semester score of less than 80, most demonstrated low willingness to learn and/or slowness in comprehending text.
3. Gender groups: This study also explored gender differences in learning outcomes using game-based instruction.

### 3.3. Research Tools

1. Game-based instruction on the topic of carbon footprint: The team expects to design the game teaching material similar to the video game modes that students used to play; thus, we applied 3D, MAX, MAYA, and Cinema 4D software in the game development. The mode of game menu we developed is same as the chatting box commonly present in smart phones and computer

games. In that case, students would have quick response to the game, which saves time for familiarising themselves with the game menu.

2. Official e-textbook on the topic of carbon footprint.
3. Pre- and post-test: The pre-test focused on government-promoted carbon reduction and environmental protection strategies, with the aim of assessing the basic carbon footprint knowledge of the two groups. The post-test focused entirely on the concept of the carbon footprint, assessing the knowledge acquired by the two groups receiving different types of game-based instruction.

### 3.4. Procedure

The experiment spanned 4 weeks. First, a pre-test featuring questions designed to test the students' knowledge of the environment and carbon reduction topics was conducted. After the pre-test, the experimental group completed a science course featuring 4 weeks of game-based instruction (one 40-minute class per week). In the first week, the course was introduced (Unit 1). Units 2 and 3 were taught in the second week, and Units 4 and 5 were taught in the third week; a post-test was administered in the final week. Each student was assigned to a computer, and the teacher explained the course content using video clips taken from the game-based instruction. The students used the computers to play the games; after completing each level, a screen with highlighted course content appeared, enabling the students to review what they had been taught. The students then completed quizzes testing their retention of the course content. The quizzes were based on three game types: Monopoly (similar to the board game Monopoly), a quiz(single/multiple choice questions), and level-based games. The teacher was allowed to assist and guide the students in answering the quiz and to let them think (Figure 5).

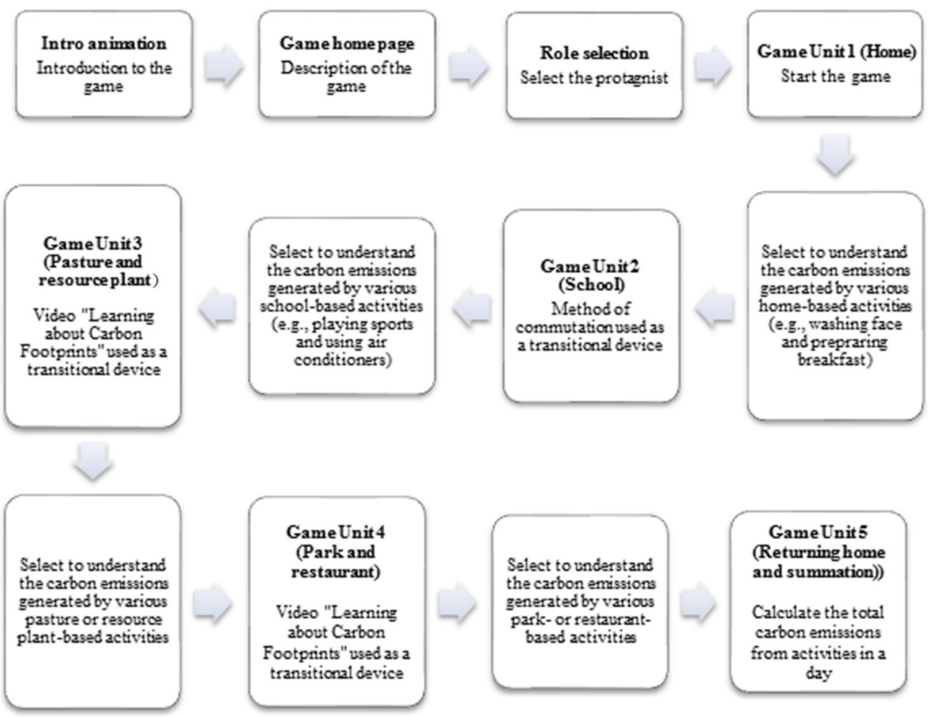


**Figure 5.** Procedure for the experimental group.

The designed content of the game-based instruction focused on "Carbon Footprint (CF)" in addition to with the RPG mode being adopted for gameplay. All the game stages in this game-based instruction are simulated reality scenes. To complete each game stage, the players take responsibility for acting out assumed roles, thus developing the plot or proceeding to the next game stage. Our proposed game consisted of the three major elements of digital games: A core theme, a story scenario, and interactivity [33]. The game content was divided according to course sections. At the beginning of the game, the students selected the characters they preferred to assume for playing the game. A game map was designed to present the course sections, with one course section being designed into one game stage. The students had to complete the following assigned tasks in each section, including course learning, video tutorials, and a quiz to proceed to the next section. As the students completed these tasks to clear the game stages, they have also completed their learning of the sectional course content. For example, in the "Understanding Carbon Footprint" unit, an animation was used to teach the students how atmospheric carbon is produced, what the characteristics of carbon are, and what a CF is. Through the video tutorials, the students acquired knowledge on topics such as how carbon is emitted into the environment, what types of activities emit carbon, and how a CF is calculated. After the students cleared a game stage, they could repeatedly play the game stage and select different actions for virtual characters to execute, thus enabling them to understand the amount of carbon emitted by different game actions, to learn which actions could reduce carbon emissions, the benefits of reducing carbon emissions, and calculating a CF.

The design method used for this study is similar to that used for the game-based learning model proposed by Garris, Ahlers, and Driskell [34], which presents in detail the aim of digital game-based learning. First, an educational game that can integrate teaching content and game characteristics is designed. Second, the designed game enables players to become immersed in the following cycles during game play: Continual problem assessment, execution of actions, and system feedback from game challenges. Finally, a specific learning objective is achieved through players' engagement with the game. In summary, digital game-based learning employs digital games incorporated with learning elements to achieve specific learning outcomes [35].

An e-textbook was used by the control group. The study period was 4 weeks (one 40-minute class per week), during which time the teacher delivered an e-textbook-based course on the concept of the carbon footprint using tools including digitized course materials, animations, and videos. A game-based practice session was completed at the end of each week.

After the experiment was completed, a post-test was administered. As with the pre-test, examination papers were distributed to the students, and their scores were recorded. The examination focused on the concept of the carbon footprint and incorporated the following question types: True or false (10), multiple choice (10), closed (5), and question and answer (Q and A) (3).

### *3.5. Measures*

1. The independent variable was the type of course material (game-based instruction versus e-textbook). The structure and content of the game-based instruction were based on elementary school science and living technology courses. Specifically, visual (animations, videos, graphics, and word cards) and auditory (sounds, dialogue, music, and positive verbal feedback) elements, together with scenario simulations, were integrated into the materials, and science-based demonstration videos featuring virtual characters were used to enable the experimental group to acquire knowledge.
2. The dependent variable was the learning outcomes of the students in the experimental and control groups.
3. The control variables were as follows:
    1. The content of the game-based instruction was consistent with that of the official textbook used in schools. During the content selection and design of the game-based instruction, a group of teachers (science teachers, class advisors, and the Director of Curriculum) were invited to assist in content adjustment and editing.
    2. The students were recruited only from regular classes; however, they were further classified into average/high- and low-score groups.

To process the experimental data, we used the SPSS for Windows statistical software package (ver. 20.0; SPSS Inc., Chicago, IL, USA). To measure changes in the students' overall knowledge and possible study of unit content before and after the game-based instruction intervention, we employed an inferential statistical technique, i.e., the paired-samples *t*-test. Together with the independent-samples *t*-test, this test was used to examine whether the experimental and control groups showed outcomes corresponding to our hypotheses.

## 4. Results

### 4.1. Paired-Samples t-Test

#### 4.1.1. Overall Learning Outcomes of the Experimental and Control Groups Regarding Carbon Footprint Knowledge

Table 1 indicates that the average pre- and post-test scores of the control group were 80.8 and 84.3 out of 100, respectively. For the experimental group, the average pre- and post-test scores were 79.8 and 86.8, respectively; the post-test score was thus 7.0 points higher. Table 1 also shows that the pre- and post-test results of the control group, who used the e-textbook, did not differ significantly ($t = -1.559$, $p = 0.13$). However, the pre- and post-test results of the experimental group, who received the game-based instruction, did show a significant difference ($t = -5.221$, $p < 0.001$).

**Table 1.** Pre- and post-test data of the experimental and control groups during the carbon footprint course.

| Group | Number of Students | Pre-Test Score | | Post-Test Score | | Difference Between Pre- and Post-Test Score | *t* Statistic |
|---|---|---|---|---|---|---|---|
| | | Avg. | SD. | Avg. | SD. | | |
| Control group (e-textbook) | 30 | 80.8 | 3.88 | 84.3 | 12.51 | +3.5 | −1.559 |
| Experimental group (game-based instruction) | 30 | 79.8 | 12.12 | 86.8 | 11.77 | +7.0 | −5.221 *** |

Avg., average; SD, standard deviation. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

The experimental and control groups differed in pre-test scores (i.e., "prior knowledge"); the average pre-test score of the experimental group was slightly lower than that of the control group. Different levels of prior knowledge may lead to different learning outcomes. To eliminate any bias arising from this factor and to verify that the two groups differed significantly in learning outcomes only due to the intervention, pre-test scores were included as a covariate in in analysis of covariance (ANCOVA), and prior knowledge was shown to have affected the post-test results ($p < 0.05$). The experimental group performed better than the control group the post-test, showing that our game-based instruction intervention enhanced learning outcomes.

#### 4.1.2. Differences in Learning Outcomes Between the Low- and Average/High-Score Groups

As shown in Table 2, the 14 students in the 60–79 pre-test score group had an average pre-test score of 69.14 (standard deviation [SD] = 7.98), an average post-test score of 79.64 (SD = 13.07), and an average difference between the pre- and post-test scores of 10.5. In contrast, the 16 students in the 80–100 pre-test score group had an average pre-test score of 89.12 (SD = 5.51), an average post-test score of 93.9 (SD = 5.41), and an average difference between pre- and post-test scores of 4.78. The average scores of both the 60–79 and 80–100 groups significantly improved post-intervention ($t = -4.89$, $p < 0.001$ and $t = -3.02$, $p < 0.01$, respectively); however, the extent of improvement in scores was greater in the 60–79 score group than in the 80–100 score group.

**Table 2.** Pre- and post-test scores of the 60–79 and 80–100 score groups.

| Group | Number of Students | Pre-Test Score | | Post-Test Score | | Difference Between Pre- And Post-Test Score | *t* Statistic |
|---|---|---|---|---|---|---|---|
| | | Avg. | SD. | Avg. | SD. | | |
| 60–79 score group | 14 | 69.14 | 7.98 | 79.64 | 13.07 | +10.5 | −4.89 *** |
| 80–100 score group | 16 | 89.12 | 5.51 | 93.90 | 5.41 | +4.8 | −3.0 ** |

Avg., average; SD, standard deviation. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

In the control group, the average pre-test score of the nine students subclassified into the low-score group (pre-test score of 60–79) was 73.33 (SD = 6.67); their average post-test score was 77.34 (SD = 7.14), and the average difference between the pre- and post-scores was significant (4.01; $t = -3.539$, $p < 0.01$) (Table 3). The average pre-test score of the 21 students in the average/high-score group (pre-test score of 80–100) was 89.34 (SD = 4.49); their average post-test score was 90.43 (SD = 8.89), and the average difference between the pre- and post-test scores was 1.09.

**Table 3.** Pre- and post-test scores of the low- and average/high-score subgroups of the control group.

| Group | Number of Students | Pre-Test | | Post-Test | | Difference Between Pre- and Post-Test Score | *t* Statistic |
|---|---|---|---|---|---|---|---|
| | | Avg. | SD. | Avg. | SD. | | |
| 60–79 score group | 9 | 73.33 | 6.67 | 77.34 | 7.14 | +4.01 | −3.539 ** |
| 80–100 score group | 21 | 89.34 | 4.49 | 90.43 | 8.89 | +1.09 | −0.636 |

Avg., average; SD, standard deviation. * $p < 0.05$; ** $p < 0.01$.

### *4.2. Results of Paired-Samples and Independent-Samples t-Tests and ANCOVA*

#### 4.2.1. Gender Differences in Learning Outcomes

In the experimental group, the average pre- (82.13) and post-test (89.63) scores of the male students differed by 7.5 points, while the average pre- (77.14) and post-test (83.64) scores of the females differed by 6.5 points; in both genders, these differences were significant ($t = -4.01$, $p < 0.01$ and $t = -3.24$, $p < 0.01$), respectively (Table 4). To eliminate the effects of prior knowledge on post-test performance, the average pre-test scores of the experimental group were included as a covariate in the ANCOVA. Levene's test showed that the average pre-test scores were not different between the male and female students (F = 0.003, $p = 0.96$). In addition, the average pre-test score (prior knowledge) had a significant influence on the post-test score (F = 48.02, $p < 0.001$). Gender had no significant effect on learning outcomes (F = 0.67, $p = 0.42$). After adjusting for prior knowledge, the average pre-test scores (males, 87.84; females, 85.68) showed that male students performed slightly better than female students on the pre-test.

**Table 4.** Pre- and post-test scores of males and females in the experimental group.

| Group | Number of Students | Pre-Test | | Post-Test | | Difference Between Pre- and Post-Test Score | *t* Statistic |
|---|---|---|---|---|---|---|---|
| | | Avg. | SD. | Avg. | SD. | | |
| Males | 16 | 82.13 | 12.44 | 89.63 | 12.33 | +7.5 | −4.01 ** |
| Females | 14 | 77.14 | 11.63 | 83.64 | 10.63 | +6.5 | −3.24 ** |

Avg., average; SD, standard deviation. * $p < 0.05$; ** $p < 0.01$.

In the control group, the average pre- (79.54) and post-test (85.23) scores of the male students differed by 5.69 points, while the average pre- (81.76) and post-test (83.53) scores of the females differed by 1.77 points; the difference was not significant in either group ($t = -2.98$ and $t = -0.53$, respectively) (Table 5). The female students showed a smaller pre- to post-test score difference than the male students.

**Table 5.** Pre- and post-test scores of males and females in the control group.

| Group | Number of Students | Pre-Test | | Post-Test | | Difference Between Pre- and Post-Test Score | *t* Statistic |
|---|---|---|---|---|---|---|---|
| | | Avg. | SD. | Avg. | SD. | | |
| Males | 13 | 79.54 | 5.3 | 85.23 | 10.73 | +5.69 | −2.98 |
| Females | 17 | 81.76 | 1.79 | 83.53 | 14.11 | +1.77 | −0.53 |

Avg., average; SD, standard deviation. * $p < 0.05$; ** $p < 0.01$.

Though the female control group students performed slightly better in the pre-test than the males, an independent-samples *t*-test (with Levene's test) revealed that the difference was non-significant. Moreover, the post-test scores of the male and female control group students did not differ significantly ($t = 0.362$, $p > 0.05$).

## 5. Discussion

The results in Table 1 show the overall learning outcomes of the experimental and control groups. The learning outcomes of the experimental group increased significantly post-intervention. In addition, the pre-test average score of the control group students, who used the e-textbook, surpassed that of the experimental group students (control group = 80.8; experimental group = 79.8). However, the post-test scores of the control group were slightly lower than their pre-test scores. This may be because the pre-test covered basic knowledge on the environment and carbon reduction strategies, which students had the opportunity to study during science lessons, social studies, and tutoring sessions. Some students were studying the topic of carbon footprint for the first time during the course proper, which had more in-depth and slightly more difficult content. The pre-test scores of the experimental group were lower than those of the control group (average difference = 1 point). However, following the introduction of the game-based instruction, the average score of the experimental group increased from 79.8 to 86.8 points for the carbon footprint unit (an increase of 7 points). We inferred that this increase occurred due to the teacher using videos from the game-based instruction module to explain and introduce the concepts of the carbon footprint and the carbon emission process to the students. In addition, the students were able to engage in gameplay and select the course unit that they wished to study (Figure 6). By including different topics at each level of the games, the students could acquire greater knowledge of the carbon footprint; such knowledge was reinforced by repetition of each level using different virtual characters. Therefore, the sensory impact of the videos and the game served to increase both the willingness and interest of the students to learn during class. The e-textbook used by the control group involved video-based lessons as well as game-based practice sessions that were not directly related to the course topic (Figure 7); this prevented the students from associating the practice sessions with the course topic. The practice sessions were not presented in a cyclic manner. As a result, several control group subjects focused solely on successful completion of the game, gaining limited information on the course content and resorting to guesswork when their answers were incorrect. Thus, two groups have experienced of the game, and the effect of two game-based instructions can be tested.

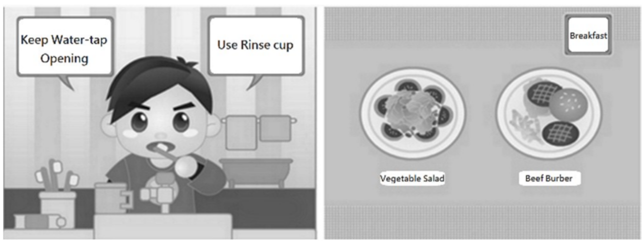


**Figure 6.** The choice of game levels.

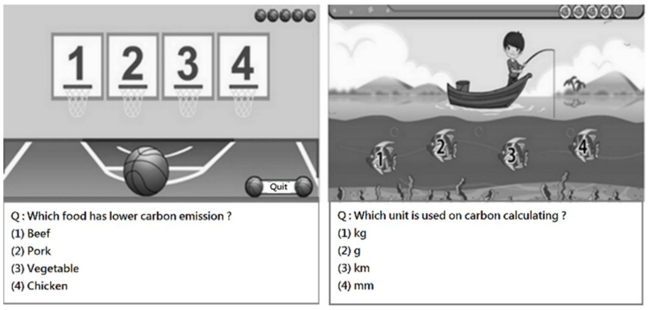


**Figure 7.** The game levels in the e-textbook.

Moreover, the number of experimental group students who responded correctly to the Q and A items, which appeared during the final section of the post-test, was measured by teachers and was higher than that in the control group. Compared with the control group, the structure and integrity of the answers given by the experimental group to the following two questions were superior: "Please briefly describe what a carbon footprint is," and "Please briefly describe what a carbon label is." This finding also showed that, compared with the e-textbook, elementary school students preferred scenario simulations, demonstrated a greater reaction and structure to the scenario simulation in the game-based instruction, and could cite examples that appeared in the materials when answering the examination questions. The answers provided by the experimental group were also more detailed. Engaging educational games can enable students to acquire in-depth knowledge and insight into course subjects [31]. In this study, the game-based instruction intervention led to favorable learning outcomes because the scenario simulation games presented a virtual environment similar to that of the learners' everyday lives and enabled them to use different approaches to absorb the course content.

As shown in Table 2, the carbon footprint-related learning outcomes of the low-score subgroup of the game-based instruction group exhibited a substantial improvement post- versus pre-test. Specifically, these students had better scores in subjects where a higher proportion of the textbook content was presented through images, such as sociology, the arts, the humanities, and these topics in combination. However, the students performed worse on text-based subjects, such as mathematics, Chinese, and English. The frequency with which text or images were incorporated into the science learning materials varied by the course unit. When a unit introduced course background information or the experimental processes that the students were expected to recite, the scores were lower than for units with content that could be understood through images. We determined that the students concentrated more and were more excited by observations and interview when the game-based instruction was employed, with some students looking forward to future classes and enquiring about the content of the next class. Furthermore, the characteristics of the game-based instruction (namely, that it offered different options for each level, virtual scenes, and multiple practice activities) enabled the students to absorb the course content more effectively. In fact, these characteristics were the main reason why the students in the 60–79 score group improved so dramatically in response to the game-based instruction.

In the control group using the e-textbook, the average/high-score subgroup improved their learning outcomes by 1.09 points, whereas their low-score counterparts improved by 4.01 points. The average/high- and low-score students in the control group showed less improvement than their experimental group counterparts. In particular, there was significantly greater improvement (by 10.5 points) in the low-score experimental group subjects versus the low-score control subjects (4.1 points). On-site observation revealed that although the e-textbook presented the course content through videos, the content was mostly in the form of text; thus, the students spent additional time examining text. Generally, schoolchildren now have more access to mobile phones and computer games; however, the game-based practice sessions built into the e-textbook compact discs used in this study have limited variety and relevance to the course topics that they cover and, thus, limited utility; hence, the students' learning motivation was reduced. By contrast, the game-based instruction encompassed scenarios closely related to many aspects of schoolchildren's daily lives and provided the user with various action options in the different scenarios; hence, the material resonated more with the students.

Regarding gender differences in learning outcomes (Tables 4 and 5), the mean difference in the experimental group (males, +7.5 points post- vs. pre-test, females, +6.5) was higher than that in the control group (males, +5.69, females, +1.77). Based on these results, the male students in the experimental group improved slightly more than those in the control group, whereas the females in the experimental group improved substantially compared with those in the control group. The marked improvement made by the female students in the experimental group indicated that the ever-increasing penetration of personal computers and mobile devices has encouraged females to play games and has led to greater diversity in the games available. In the experimental group, the female students played scenario simulation games repeatedly and selected different actions to learn about the carbon footprint. They also related the content to real-life situations that they had knowledge of and selected different characters during gameplay. For male students, the scenes in the game-based instruction that linked one game level to another incorporated different video clips. For example, Game Unit 4 introduced an item selection screen in which players could press buttons to select video clips and scenes pertaining to low-carb diets. The players could also browse a shelf of products with labels containing carbon-related information present in the background. Male students were likely to pay attention to the background labels and to click on them with the mouse and thus gain additional knowledge.

In the control group, the male students improved moderately, whereas the females improved only slightly. The majority of the female students discontinued their participation in the e-textbook games after playing them once or twice and demonstrated less interest in the practice sessions than did their male counterparts.

## 6. Conclusions

The results of this study indicated that the students were highly interested in the game-based learning method, which integrated knowledge with gameplay by presenting the content of textbooks as images and simulations. The participants could acquire carbon footprint knowledge by completing the levels of the game and then test their knowledge via quizzes during gameplay, receiving instant feedback and a sense of accomplishment. We also divided the students into groups according to their ability and the experimental conditions to examine the effectiveness of the game-based instruction. The students in each learning condition were further subdivided into average/high- and low-score groups. The students in the low-score group were generally those who could not concentrate fully during study and/or had slow comprehension. After the game-based instruction intervention, the improvement rate of the students in the low-score group was clearly greater than that of the high-score group, thereby indicating that the game-based instruction increased concentration.

In addition, the knowledge of female students in the experimental group improved significantly more than that of their control group counterparts and at almost the same rate as that of male students in the same group; this dovetails with the general increase in the number of female game players, with continual technological advances ensuring the ubiquity of smartphones and tablet computers that in turn contribute toward a reduction in the gender difference in games participation. The conclusion is drawn plainly from the data, while gender identity has been taken into consideration in analysis. In addition, the findings echoed previous studies and showed that the scenario simulation gameplay in a teaching context can facilitate learning.

In this study, acquiring knowledge of textbook content converted into images through game-based instruction improved students' comprehension and learning motivation. Thus, we anticipate that useful teaching tools will be informed by this method in the future. E-textbooks should be used with consideration of students' reading habits and learning styles, where such digital materials are designed to aid learning and should be applied with specific objectives in mind. Without these considerations, users may not reach their potential in the digital era [1]. In addition to game-based instruction provided by textbook publishers officially approved by the Taiwan Ministry of Education, the game-based instruction developed in this study could serve as a beneficial tool to assist teachers in instructing students. The results of this study could be applied in the context of special education classes; on the basis of our findings, whether game-based instruction increases the learning intention of such students should be investigated. Future research could also address how well such students accept game-based instruction, where such data could then be applied to improve game content and help special education students become more attentive in their studies.

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