Experiment Design

Participants

The subjects included two classes of fifth graders of an elementary school in Tainan County in Taiwan. A total of forty-six students voluntarily participated in the study. One class was assigned to be the experimental group and the other was the control group. The experimental group, including twenty-four students, was guided by the personalized educational computer game that met the learning styles of individual students, while the control group with twenty-two students was guided by the educational computer game that did not meet their learning styles. All of the students were taught by the same instructor who had taught that natural science course for more than ten years.

Research Tools

The research tools in this study included the learning style measure, learning achievement tests, and the questionnaire for measuring the students' learning motivation and technology acceptance.

The Index of Learning Styles (ILS) Questionnaire was developed by Soloman and Felder (2001) based on the learning styles proposed by Felder and Silverman (1988). The original ILS measure consists of four dimensions (i.e., sensing/intuitive, visual/verbal, active/reflective and sequential/global), each of which contains 11 items. In this study, the "sequential/global" dimension is adopted.

The test sheets were developed by two experienced teachers. The pre-test aimed to evaluate the students' prior knowledge of learning the course unit "knowing the plants on the school campus". It contained fifteen yes-or-no items, fifteen multiple-choice items and nine fill-in-the-blank items, with a perfect score of 100. The post-test contained ten multiple-choice items and fifteen fill-in-the-blank items for assessing the students' knowledge in identifying and differentiating the plants on the school campus. The perfect score of the post-test was 40.

The questionnaire of learning motivation was modified from the measure developed by

Pintrich and DeGroot (1990). It consisted of ten items (e.g., "Compared with other students in this class I expect to do well" and "It is important for me to learn what is being taught in this class") with a seven-point rating scheme. The Cronbach's alpha value of the questionnaire was 0.87.

The technology acceptance questionnaire originates from the questionnaire developed by Chu, Hwang, Tsai, and Tseng (2010). It consists of 13 items with a six-point Likert rating scheme, including 7 items for “Perceived ease of use” and 6 items for “Perceived usefulness”. The Cronbach's alpha values of the two dimensions are 0.94 and 0.95, respectively.

Experiment Procedures

Before the experiment, the two groups of students took a two-week course about the basic knowledge of the plants, which is a part of the existing natural science course. Figure 4 shows the flow chart of the experiment. At the beginning of the learning activity, the students took the learning style measure, the pre-test and the learning motivation questionnaire. During the learning activity, the students in the experimental group learned with the personalized educational computer game which provided the user interface based on their learning styles; on the other hand, those in the control group learned with the educational computer game that did not meet their learning styles. Both versions of the game contained the same background story, learning missions and learning content. The time for the students to complete their learning missions was sixty minutes. After the learning activity, the students took the post-test and the motivation questionnaire for measuring their learning achievements and any change in their learning motivation.

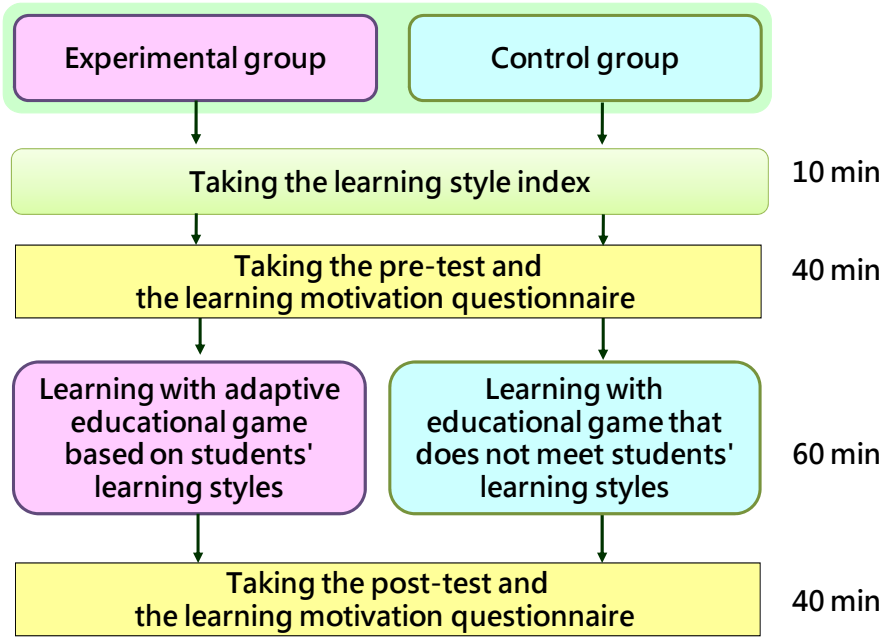

Figure 4. Diagram of experiment design

Results

Analysis of Learning Achievement

The aim of this study was to examine the effectiveness of the personalized educational computer game in improving the learning achievement of the students. The mean values and standard deviations of the pre-test scores were 94.73 and 6.17 for the control group, and 96.29 and 3.68 for the experimental group. The *t*-test result (t=0.297, p >.05) shows that there was no significant difference between the two groups; consequently, it is evident that the two groups of students had equivalent prior knowledge before the learning activity, as shown in Table 1.

Table 1. t-test result of the pre-test scores

		N	Mean	S.D.	*t*
Pre-test	experimental group	24	96.29	3.68	0.297
	control group	22	94.73	6.17	

After the learning activity, the analysis of covariance (ANCOVA) was used to test the difference between the two groups by using the pre-test scores as the covariate and the post-test scores as dependent variables. The adjusted mean value and standard error of the post-test scores were 20.69 and 0.86 for the control group, and 23.28 and 0.83 for the experimental group. According to the

results (F=4.64, p<.05), there was a significant difference between the two groups; that is, the students who learned with the personalized educational computer game showed significant better learning achievements than those who learned with the game that did not meet their learning styles.

Table 2. Descriptive data and ANCOVA of the post-test results

Group	N	Mean	S.D.	Adjusted Mean	Std.Error.	*F*
Experimental group	24	23.43	3.24	23.28	0.83	4.64*
Control group	22	20.41	5.29	20.69	0.86	

*p<.05

Analysis of Learning Motivation

Table 3 shows the *t*-test result of the learning motivation pre-questionnaire ratings of the two groups. The means and standard deviations of the pre-questionnaire ratings were 5.47 and 0.87 for the experimental group, and 5.28 and 0.95 for the control group. The *t*-test result showed no significant difference between the pre-questionnaire ratings of the two groups (t=0.69, p＞.05), showing that the two groups of students had equivalent learning motivation before participating in the learning activity.

Table 3. *t*-test result of the pre-test scores of the two groups

Group	N	Mean	S.D.	*t*
Experimental group	24	5.47	0.87	0.69
Control group	22	5.28	0.95	

After the learning activity, the two groups of students took the learning motivation post-questionnaire. Table 4 shows the ANCOVA result of the post-questionnaire ratings of the two groups. The means and standard deviations of the ratings were 5.79 and 0.9 for the experimental group, and 5.23 and 1.35 for the control group. It is found that the post-questionnaire ratings of the two groups were significantly different (F=4.24, p<.05). As the adjusted mean of the experimental group (5.7) was significantly higher than that of the control group (5.33), it is concluded that the personalized educational computer game had a significant impact in improving the students' learning motivation toward the natural science course.

Table 4. ANCOVA result of learning motivations on the post-test scores of the two groups

Group	N	Mean	S.D.	Adjusted Mean	Std.Error.	*F*
Experimental group	24	5.79	0.90	5.70	0.12	4.24*
Control group	22	5.23	1.35	5.33	0.13	

* $p < .05$

Analysis of Perceived Ease of Use and Usefulness

To better understand the students' perceptions of the use of the educational computer game, this study collected the students' feedback in terms of "perceived usefulness" and "perceived ease of use", as shown in Table 5. It is found that most students gave positive feedback concerning the two dimensions of the educational computer game. The average ratings for "perceived usefulness" are 5.06 and 4.74 for the experimental group and the control group, respectively; moreover, their average ratings for "perceived ease of use" are 5.23 and 4.86. In comparisons with ratings given by the control group, it should be noted that the students in the experimental group gave higher ratings to "perceived usefulness" and "perceived ease of use", implying that the students who learned with the personalized educational computer game that met their learning styles revealed higher degrees of technology acceptance than those who learned with the game that did not meet their learning styles.

In terms of perceived usefulness, the average ratings of the items "The educational computer game provides the learning content in a vivid way", "The educational computer game is helpful to me in learning new knowledge", "The game-based learning approach smoothed the learning process" and "The game-based learning approach is helpful to me in realizing the learning content" from the experimental group are higher than 5.0, implying that most students in the experimental group identified the usefulness of the personalized game-based learning approach in improving their learning achievements. Such a finding is consistent with the analysis result of the learning achievements.

In terms of perceived ease of use, the items "I learned how to use the educational computer

game quickly" and "Operating the educational computer game is not difficult for me" received the top 2 average rating from the experimental group, implying that most students in the experimental group felt that the personalized educational computer game was easy to get familiar with and operate even though the students had never play the game before the learning activity.

Table 5. Questionnaire results about perceived ease of use and usefulness of using the educational computer game

Dimension	Questionnaire item	Group	mean	S.D.
Perceived Usefulness	The educational computer game provides the learning content in a vivid way.	Experiment	5.29	0.96
		Control	5.00	1.20
	The educational computer game is helpful to me in learning new knowledge.	Experiment	5.17	0.87
		Control	4.82	1.22
	The game-based learning approach smoothed the learning process.	Experiment	5.17	0.87
		Control	4.73	1.39
	The game-based learning approach is helpful to me in realizing the learning content.	Experiment	5.17	0.70
		Control	4.77	1.11
	I feel that I can learn better with this game-based learning approach.	Experiment	4.92	0.97
		Control	4.68	1.25
	Such a learning approach is more effective than other computer-assisted learning approaches I have experienced.	Experiment	4.67	1.31
		Control	4.45	1.37
	Average	Experiment	5.06	0.78
		Control	4.74	1.13
Perceived Ease of Use	It is not difficult to use the educational computer game.	Experiment	5.33	0.76
		Control	5.00	1.41
	I do not need to put in lots of effort during the learning activity.	Experiment	4.92	1.10
		Control	4.41	1.84
	The learning content is easy to understand.	Experiment	4.96	0.81
		Control	4.50	1.34
	I learned how to use the educational computer game quickly.	Experiment	5.46	0.72
		Control	5.18	1.14
	Operating the educational computer game is not difficult for me.	Experiment	5.42	0.72
		Control	4.95	1.43
	It is very easy to work with the interface of the educational computer game.	Experiment	5.33	0.76
		Control	5.09	1.31
	Generally speaking, the educational computer game is easy to use.	Experiment	5.21	0.93
		Control	4.91	1.38
	Average	Experiment	5.23	0.56
		Control	4.86	1.22

Table 4. t-test result

認知易用性		N	Mean	S.D.
1.在這次的學習過程中，我覺得遊戲的操作並不困難。	experimental group	24	5.33	0.76
	control group	22	5.00	1.41

2.在這次的學習過程中，並不需要花費過多的時間精力。	experimental group	24	4.92	1.10
	control group	22	4.41	1.84
3.本次學習活動的遊戲內容對我而言是清楚且容易理解的。	experimental group	24	4.96	0.81
	control group	22	4.50	1.34
4.我很快地瞭解本遊戲的操作方式。	experimental group	24	5.46	0.72
	control group	22	5.18	1.14
5.本次學習活動中，操作遊戲的過程對我來說沒什麼困難。	experimental group	24	5.42	0.72
	control group	22	4.95	1.43
6.我會主動搜尋更多與自然科學有關的內容。	experimental group	24	5.33	0.76
	control group	22	5.09	1.31
7.整體而言，本次活動的遊戲是容易使用的。	experimental group	24	5.21	0.93
	control group	22	4.91	1.38
總計	experimental group	24	5.23	0.56
	control group	22	4.86	1.22

認知有用性				
1. 我覺得使用這樣的遊戲學習方式讓學習的內容更生動。	experimental group	24	5.29	0.96
	control group	22	5.00	1.20
2. 我覺得使用這樣的遊戲學習方式對於我學習新知識很有幫助。	experimental group	24	5.17	0.87
	control group	22	4.82	1.22
3. 這樣的遊戲學習方式讓我的學習過程更順利。	experimental group	24	5.17	0.87
	control group	22	4.73	1.39
4. 這樣的遊戲學習方式可以幫助我理解所要學習的內容。	experimental group	24	5.17	0.70
	control group	22	4.77	1.11
5. 這樣的學習方式可以讓我學習得更好。	experimental group	24	4.92	0.97
	control group	22	4.68	1.25
6. 本次學習活動中，使用這樣的遊戲學習方式比一般的電腦學習更有效果。	experimental group	24	4.67	1.31
	control group	22	4.45	1.37
總計	experimental group	24	5.06	0.78
	control group	22	4.74	1.13