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The Application of Game-Based e-Learning for the Learning of Linear Equations in Two Unknowns

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ABSTRACT. *This study aimed to delve into the effects of game-based e-learning on junior high school students' learning effectiveness and learning attitudes when learning about linear equations in two unknowns in mathematics. The study adopted a quasi-experimental design, and the participants were Grade 8 students (57 students) in one junior high school in Pingtung County, divided into a group experiencing game-based e-learning (28 students) and a group using traditional instruction (29 students). Before the experiment, a pretest was conducted. After 12 weeks of classes, a posttest was employed. The collected data were analyzed by descriptive statistics, a one-sample t test, single-factor univariate and covariance analysis and a paired sample t test. The findings show that the experimental group is significantly satisfied with the digital game design of "Math around the World". Their digital game learning belief is significant and positive. The experimental group's learning effectiveness when being instructed in linear equations in two unknowns is significantly enhanced. The learning effectiveness of both the experimental and control groups are not significantly different. Finally, the findings of this study provide specific suggestions for the design and instruction of digital games.*

Keywords: *game-based e-learning, linear equations in two unknowns, learning effectiveness,*

learning attitude

1. Introduction

1.1. Research Background and Motives

The generation after 1980 was born in a digital environment. Their lives, learning, entertainment and even thoughts are considerably influenced by computers. They receive a great amount of digital knowledge and naturally use digital language and tools in their lives. This generation is called “digital natives” (Li, 2010). Digital natives are at good at working on several tasks at the same time. They have immediate online interactions with different people, enjoy receiving information through multimedia and are used to randomly browsing hyperlink information. They prefer videos to words and enjoy demonstrating their abilities, establishing mobile lives and living between the virtual and the real world (Prensky, 2001b). Hence, computer-based instruction based on videos, animation and sound for personalized interactive learning has become a new trend in learning.

Compared to other types of e-learning, game-based e-learning provides specific rules and goals, and it guides learners to expand their learning step by step, create real learning experiences, increase learning interest and concentration and enhance learning achievement in challenging and interesting situations (De Freitas, 2006; Liang, Chen, Yang, & Yang, 2008; Tsai, Yu, & Hsiao, 2010). In recent years, e-learning has become important. Among all subjects, mathematics is the most difficult for many students. How can we apply digital games for mathematics instruction to enhance learning interest and confidence? Good instructional design can guide successful instruction (Chien, 2005). Game-based e-learning’s emphasis on playfulness might be questioned: if learners have fun playing games, is their learning effectiveness enhanced? According to related research, game-based e-learners try to escape from learning, and the learning effectiveness of games is uncertain. The reason for this uncertainty can be poor digital game design (Tsai et al., 2010). Currently, digital instruction game design is based on creating an entertaining effect. How can we design games to accomplish instructional purposes, and how can we demonstrate different instructional effects using games (Huang, Tseng, Weng, & Ho, 2008)? Although some digital games are designed with specific instructional objectives, do they balance entertainment with the learning objectives?

Based on the above, this study will probe into the combination and application of design and instructional models for digital games and compare the effectiveness of game-based e-learning and traditional learning.

1.2. Purpose of Study

The purpose of this study aimed to

1) develop a game-based e-learning application for the instructional process for linear equations in two unknowns.

2) analyze a game-based e-learning model to measure junior high school grade 8 students' learning effectiveness when being instructed in linear equations in two unknowns.
3) study the effects of the game-based e-learning model on junior high school grade 8 students' learning attitude toward learning about linear equations in two unknowns.
4) compare the learning effectiveness of "game-based e-learning" and "traditional instruction" when used to teach linear equations in two unknowns.

2. Literature Review

2.1. Digital games and learning

Games are essentially the epitome of reality (Williamson, Squire, Halverson & Gee, 2005). In unreal situations, players can express themselves without embarrassment (Wang & Wang, 2011). Hence, individuals have the most natural self-expression and interpersonal communication model. Through their roles in games, they practice life skills, develop social relationships and show feelings (Lin, Lin, & Lin, 2010). Digital games refer to games based on information technology. Participants must follow the rules and demonstrate immediate and real reactions. These types of games satisfy their desire for interpersonal communication (Li & Wang, 2010). The key is that digital games have characteristics that encourage players to continue playing the game, such as satisfaction, desire, anger, playfulness, sense of achievement and peers' admiration (Connolly & Stansfield, 2006; Garris, Ahlers, & Driskell 2002). Hence, digital games are fantastic; they provide rules and goals, excitement, challenge, and mystery, while remaining controllable. When digital games are used in education, the users will concentrate more on learning (Hsiao, Huang, Hong, Lin, & Tsai, 2010).

Not all the themes for digital games are positive. However, even the strictest critic of digital games should agree that people can acquire knowledge and capabilities from games (Williamson et al.; 2005). The realistic characteristics of digital games guide learners to directly apply learning to solve possible obstacles in their lives. In comparison to traditional learning, learners using digital games experience more profound knowledge acquisition (Chien & Liu, 2009; Wang et al., 2011). In a virtual world, symbols and words are specified through experience; learners can comprehend more complicated concepts and do not neglect the connection between abstract concepts and real problems (Williamson et al., 2005). Research has demonstrated that compared to the previous generation, digital natives are more experienced in information processing (Prensky, 2001a). Therefore, digital games are treated as measures to enhance learning and increase the self-esteem of students who lack interest or confidence. Shaffer, Squire, Halverson, and Gee (2005) indicated that games lead to flow experience. In the process, learners absorb the knowledge required to challenge the games. When games and learning objectives are related, there can be considerable learning effectiveness. In comparison to traditional instruction, digital games have the advantage of time. In other words, learners can play games at the appropriate time and move to the next task after accomplishing a particular stage of learning (Connolly et al.; 2006). Game-based e-learning, which combines digital games with instructional content, has become a new learning trend.

Digital games have been applied to various types of training and instruction. Williamson et al. (2005) emphasized that if learners experience self-learning without specific instruction, their learning experience will be fragmented. Lin et al. (2010) suggested that instructional objectives should not be neglected by focusing on games. Effective game-based e-learning does not mean totally replacing traditional instruction with games. It is a blended learning model that is primarily based on class instruction and supported by digital game learning. Students thus follow instructional plans. Hence, games should include complete educational concepts and specific instructional objectives and content to lead to maximum effectiveness (Li et al., 2010).

2.2. Digital games and instructional design

Digital games have been applied to instructional sites for years. However, research findings have been both negative and positive (Prensky, 2001a): games usually offer users practice without learning effectiveness. Users obtain scores by simple reflection and do not enhance learning (Garris et al.; 2002). Game design will fail if it emphasizes the entertainment effect and neglects educational objectives (Van Eck, 2006). Game design based on instructional goals is the key to success for game-based e-learning. Hence, evaluating the learning quality of digital games has become important, and people have started developing related rules and standards (Chen, 2005). A check list is the most common evaluation tool for e-learning, and it serves as reference for instructors to select e-learning teaching materials (Chen & Chen, 2006). The evaluation indicators for domestic and foreign digital games are shown in Table 1.

Table 1. Evaluation indicators of domestic and foreign digital games

Researchers/research institutes	Evaluation indicators
E-Learning Accreditation and Information Exchange, MOE, ROC (2013)	1. Content and framework of teaching materials. 2. Design of teaching materials. 3. Supplement design. 4. Media and interface design.
epprobate (2013)	1. Curriculum design. 2. Instructional method. 3. Media design. 4. Content of teaching materials.
I/ITSEC of U.S.	1. Instructional characteristics: instructional content, instructional activity, performance evaluation and performance feedback. 2. User interface: guidance, content presentation and facilities.
Diana Mungai et al.	1. Learning retention. 2. Concept review. 3. Content review. 4. Learning reflection. 5. Introduction of new concept. 6. Teachers' ease of use. 7. Learners' ease of use. 8. Maintenance requirement. 9. Limitation on number of users. 10. Technical requirement for use.

Source: Compiled by this study

Jou and Sun (2008) suggested that digital game design applied to instruction should include the interface, interactive stories and balance. According to Wang et al. (2011), digital games should offer goals, rules, competition, challenge, imagination, security and entertainment. Gentile et al. (2005) made the following suggestions: (1) games should have specific goals and offer different degrees of difficulty to match individual differences; (2) in the design, learners should learn according to their adaptive learning ability; (3) through immediate feedback, games should transform learning into active practice; once learners control the right knowledge or skills, they should master learning through practice to maintain the knowledge and skills learned; (4) games should be designed to trigger the learners' external learning motivation (such as collecting points and making money) and internal learning motivation (such as the enhancement of degrees and increased abilities) by design; (5) the difficulty and complexity of games should increase; final success should depend on mastery of the previous material; (6) at the beginning, learners should obtain immediate feedback as an incentive for learning. Feedback from the game should continue to maintain learning motivation. Finally, games should provide sufficient clues in the situations to assist with learners' judgment.

Based on the above, this study adopts the evaluation indicators of learning APP proposed by the E-learning Quality Service Center (eLQ) of Taiwan in 2012, as shown in Table 2.

Table 2. Evaluation indicators of learning APP of eLQ

Dimensions	Items	Descriptions
Instruction of teaching materials	1.1 Instructional objectives	Teaching materials are based on complete instructional objectives, and they can be completely presented for users' learning.
	1.2 Instructional methods	Teaching materials are based on proper instructional methods to effectively help users accomplish learning objectives.
	1.3 Practice and evaluation (not necessary)	Teaching materials are based on appropriate practice and evaluation to help users recognize learning effectiveness and gaps.
	1.4 Consistency	Teaching materials are consistent. In other words, the instructional purposes of the teaching materials match the related content, learning activities, practice and evaluation.
Organization of content	2.1 Precision of content	The content of teaching materials is precise and stereotypes should be avoided. Content should match the users' levels.
	2.2 Completeness of content	Content of teaching materials is complete with appropriate division. It matches reading and learning of mobile devices.
Completeness of functions	3.1 Efficacy of performance	APP demonstrates high efficacy and stability. When the program stops, it will not crash the system. It indicates operational environment with high efficacy.
	3.2 Function of guidance	APP functions are simple, easy and can be operated intuitively. Names and functions are consistent, and they can guide the users.
Use interface	4.1 Ease of use	APP allows users to easily and rapidly learn, comprehend and use the functions. The interface design matches characteristics of mobile devices and is consistent.

	4.2 Media elements	Use of APP media elements matches the principle of multimedia design. The guidance images, names and functions are easily identified and recognized by users. Media use matches general habits of use and basic needs.

Source: E-learning Quality Service Center of Taiwan, 2012.

Without appropriate learning strategies, digital games will simply be entertainment (Yang, Lin, Wang, & Huang, 2011). Pivec, Dziabenko, and Schinnerl (2003) and Jou et al. (2008) suggested that in game-based e-learning, teachers are no longer the knowledge providers. They are activity designers, learning partners and learning guides. In the process, they help and instruct students to learn collaboratively and actively construct knowledge. Sun (2011) indicated that teachers' control is critical for the effectiveness of game-based e-learning. According to De Freitas (2006), the teachers' unfamiliarity with the teaching materials for games is the primary cause of failure. Hence, before implementation, teachers must be familiar with the content of the games and the instructional application to accomplish learning effectiveness.

Based on the above, the design of digital games and the teachers' role are the key to learning success. To probe into effectiveness of the application of digital games to instruction in linear equations in two unknowns for mathematics and given the concerns regarding the operation of school and home computers and the limited time for game development, this study adopts a digital game based on thinking challenges and constructs rules using world travel routes. The game provides tasks related to linear equations in two unknowns and challenges students. The difficulty increases with each net unit theme. Teachers play the role of guides, controlling the students' learning to help them at the right time.

2.3. Math learning beliefs

In 2012, *Education Parenting Family Lifestyle* conducted an "investigation on the learning of junior high school students" and demonstrated that 55.5% of the students suggested that they did not have strong learning motivation; 27.6% were not confident about their learning. Without exams, fewer than 30% (22.6%) of them actively studied. These numbers show that cancelling exams cannot enhance students' learning motivation and passion. Changes in traditional instruction and the development of new strategies to upgrade instruction are critical throughout the 12-year national education system (Ho, 2012). According to the investigation, 48.3% find mathematics to be the most difficult subject, which is the highest of all subjects. These statistics demonstrate the necessity of enhancing junior high school students' math learning interest and attitude.

Wu and Ge (2006) defined the learning attitude toward mathematics as the individuals' general views, preference for or dislike of mathematics. The learning attitude is divided into confidence, attitudes towards success, beliefs regarding usefulness and the motivation to study mathematics. Confidence reflects the learners' confidence in their math ability and performance. The attitude toward success represents the learners' expectation in terms of a successful outcome in math.

Beliefs regarding usefulness are the learners' views on the current function of mathematics, their future education, their potential occupation and other activities. Motivation to study mathematics is the learners' desire to actively study mathematics. The learning attitude influences the learners' learning effectiveness in mathematics. Thus, intellectual, educational and interesting math games will trigger learning motivation and maintain interest (Wu & Su, 1995).

In the motivation theory of Pintrich (1989), learning motivation is classified into value, expectation and affection. Value represents the reason why learners' learn and the importance, value, effectiveness and interest of their learning. Expectation represents the learners' cognition of personal capacity and skill after accomplishing learning tasks. Affection is the learners' emotional reaction toward learning according to their evaluation of their learning performance and self-capacity. The degree of learning motivation influences not only learning continuity but also the learners' learning attitude, behavior and use of strategy.

Based on the above, this study defines the digital game learning belief as follows: "students' views or learning about math using a digital game in a process of game-based e-learning, and their cognition and experience of the results of math learning. Digital game learning can be a passive or an active learning behavioral intention".

3. Research Design

3.1. Research Structure and Design

This study primarily probes into the effect of game-based e-learning on learning effectiveness in mathematics. The research framework is shown in Figure 1.

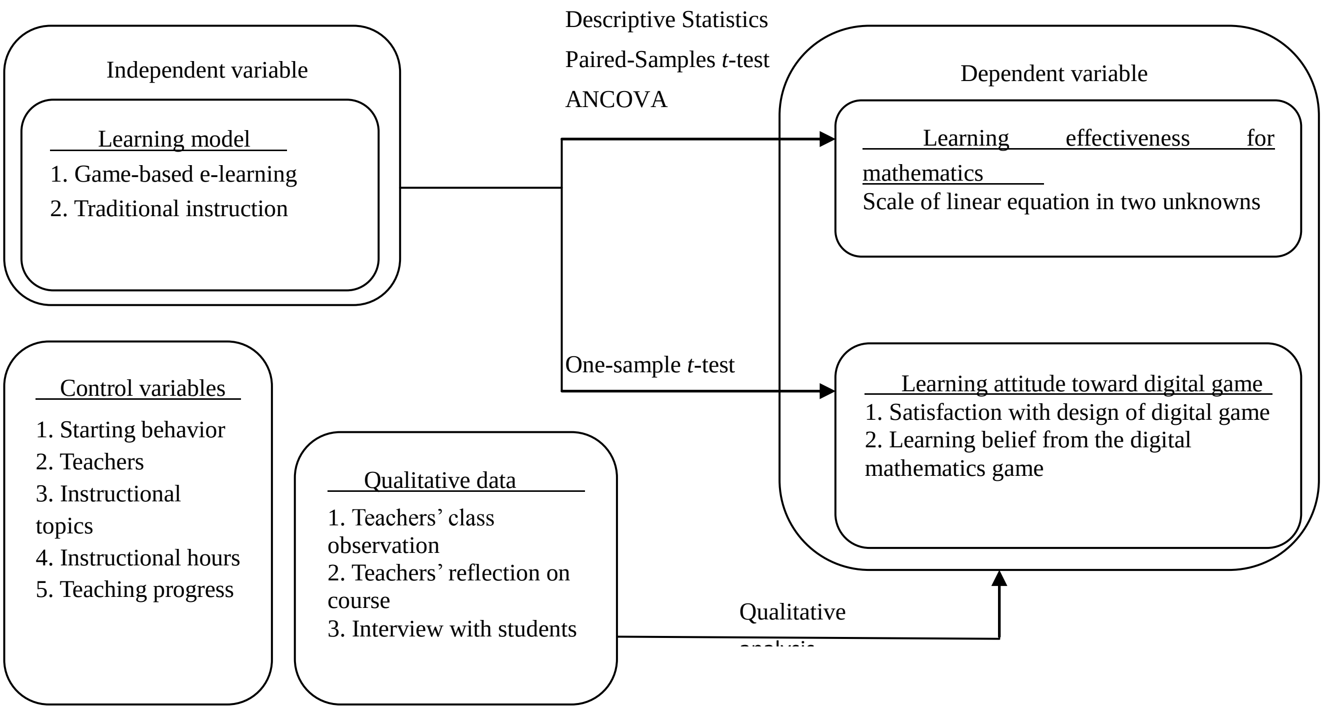

Figure 1. Research Structure

This study adopted a quasi-experimental design. Before the experiment, the researcher conducted a pre-condition pretest on the experimental and control groups. After the experiment, a posttest was conducted. The attitude toward the digital game was investigated for the experimental group, and this study interviewed students regarding their learning. The instructional experiment lasted for 12 weeks, for one hour each week. The researcher played the role of instructor. The instructional content and progress were the same. The instructional steps are shown in Figure 2.

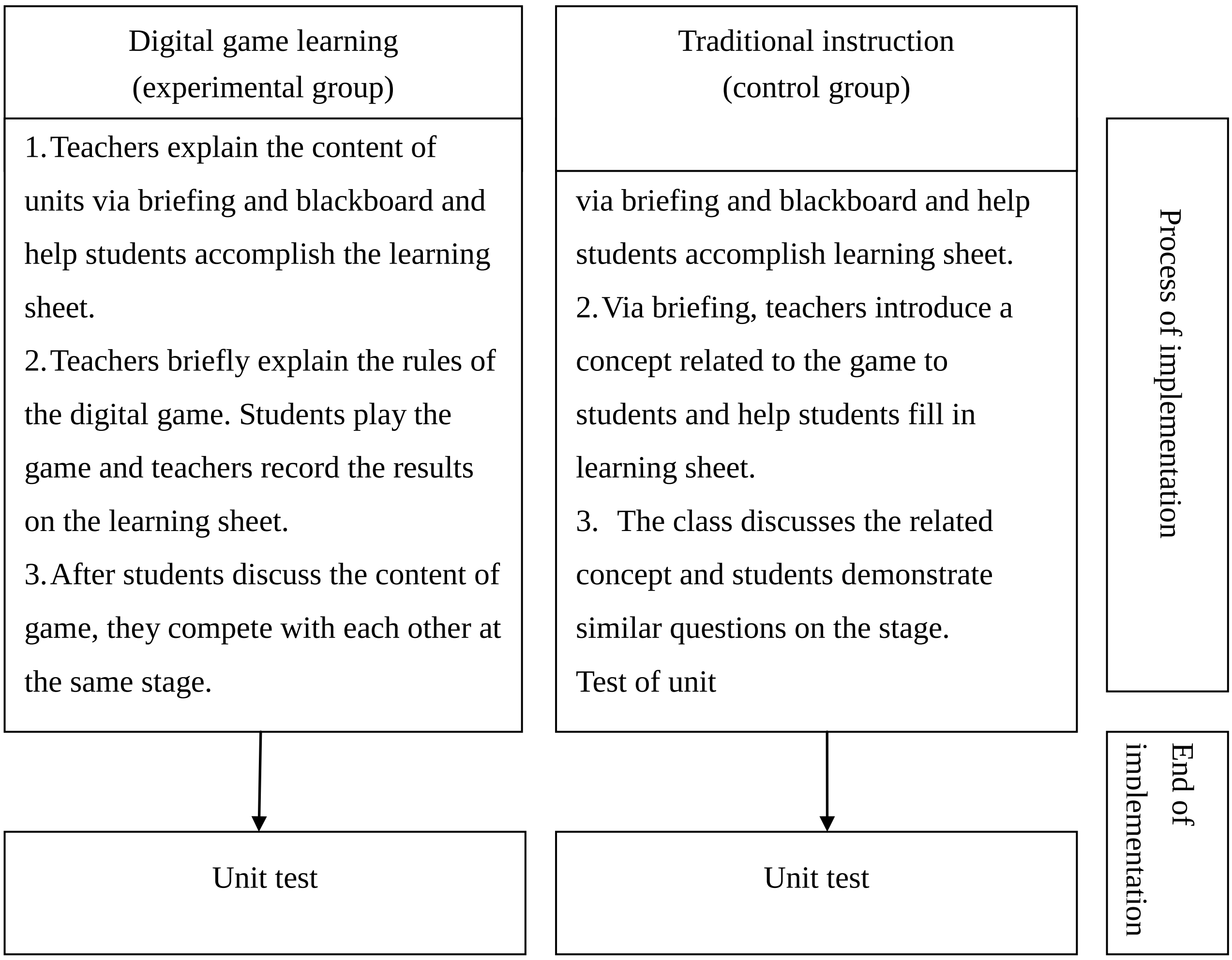

Figure 2. Instructional steps for the experimental and control groups

3.2. Research Subjects

The participants were two classes of Grade 8 students in junior high school, including 28 students in the experimental group and 29 students in the control group. These students have learned linear equations in two unknowns over eight weeks in Grade 7 and understood the basic concept.

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3.3. Research Tools

Math around the World: according to the learning objectives for linear equations in two unknowns and the design principle of the digital game based on the literature review, this study designed a digital game based on world flight routes with Han Line Publishing Co. Ltd.

(1) Design of Game

According to degree from bottom to top, the game includes four stages: introduction of countries by coordinates, acquisition of equation between two cities, acquisition of cross-point between the two routes and assessment of the operational profit of the routes, as shown in Figure 3. After the game is started, passwords are shown at each stage, including the rules of game, the learning concept and the standards to pass the stages, as shown in Figure 4.

Description

Figure 3. Front page of game

Figure 4. Password

After responding to a question, the students immediately obtain feedback. They can resubmit answers without limitation and there is no punishment, as shown in Figures 5 and 6. When the scores pass the required standard, the computer will show an image for passing the stage, as indicated in Figure 7. To plan learning time, the learners can directly enter a specific stage without completing the easier stages, as shown in Figure 8.

Figure 5. Correct

Figure 6. Wrong

Figure 7. Passing the stage

Figure 8. Selection of the next stage after passing the stage

First stage "introduction of countries by coordinates": the computer randomly selects one coordinate. The learners note the correct position on the right angle axes, as shown in Figure 9. They must pass the stage by providing 10 correct answers. After they submit the right answers, the computer shows the name of the country and an introduction at the coordinate, as indicated in Figure 10. The purpose of this stage is to allow the students to become familiar with right angle axes and to introduce knowledge of world geography.

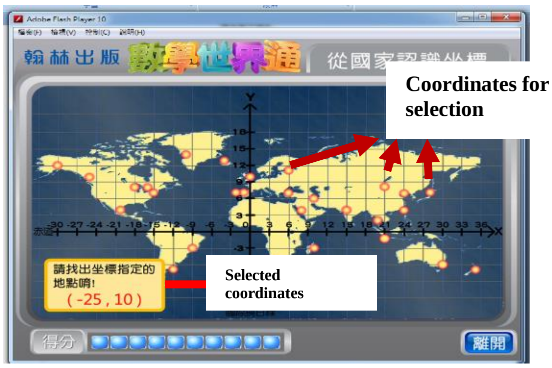

Figure 9. Image for the first stage

Figure 10. Introduction to the country

Second stage "acquisition of equation between two cities": the computer randomly selects two cities and their coordinates and calculates the linear equation that passes through these two points. Four items are provided, as shown in Figure 11. The students pass the stage by having 10 correct answers. After filling in some items correctly, the computer will show the origins of the city, as indicated in Figure 12. The purpose of this stage is to allow students to become familiar with the solution of a linear equation for two points and to learn the meaning of a linear equation in two unknowns.

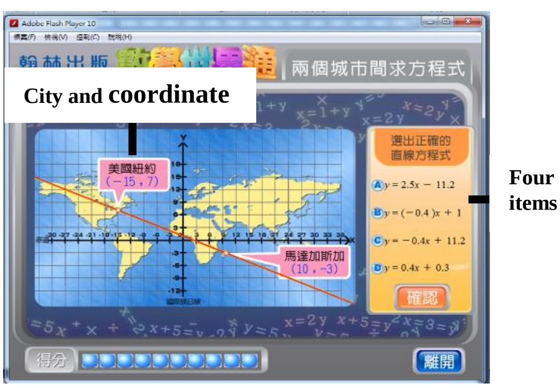

Figure 11. Image for the second stage

Figure 12. Interesting origin

Third stage "acquisition of a cross-point between two routes": the computer randomly selects two routes and provides the linear equations. The students should obtain the cross-point of the two routes. This stage is based on filling blanks, as shown in Figure 13. Students pass this stage by having five correct answers. After the students fill in the right answer, the name of the country at the coordinate will be shown, as indicated in Figure 14. The purpose of this stage is to allow students to become familiar with solving simultaneous linear equations in two unknowns.

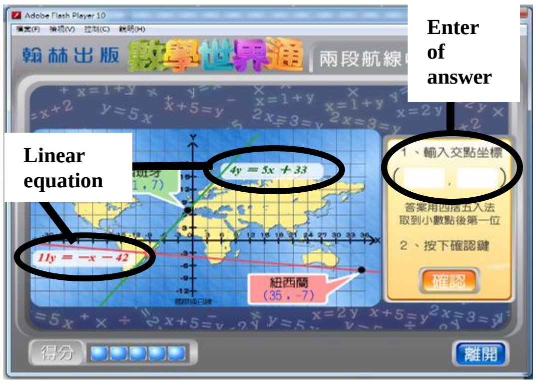

Figure 13. Image for the third stage

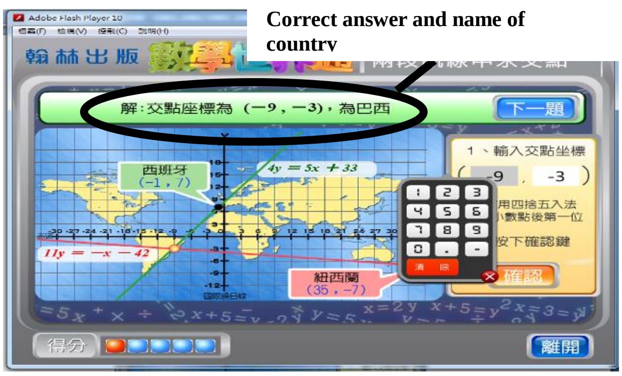

Figure 14. Correct answer and name of country

(2) Evaluation indicator analysis of learning APP of eLQ

Table 3. Analysis of the evaluation indicators

Dimensions	Items	Match: Totally matched	Match: Partially matched	Match: Totally not matched	Descriptions
Instruction of teaching materials	Instructional objectives	✓			
	Instructional methods	✓			
	Practice and		✓		With evaluation, learners can

	evaluation (not necessary)			avoid learning by guessing the answers
	Consistency	✓		
Organization of content	Correct content	✓		
	Complete content	✓		
Completeness of functions	Efficacy		✓	Operational environment without indication of good efficacy
	Guidance function	✓		
Use of interface	Ease of use	✓		
	Media elements	✓		

(3) Pretest and posttest scales for linear equations in two unknowns

The scale was designed by the researcher according to the outlines for simultaneous linear equations in two unknowns, right angle axes and linear equations in two unknowns for mathematics in junior high school. Four experienced math teachers were invited to revise the scale, providing expert validity. The pretest scale is based on filling the blanks. According to difficulty, the pretest scale is scored from 1 to 6 points. There are 22 items and the total score is 100. According to difficulty, the posttest scale is scored from 2 to 6 points. There are 20 items, and the total score is 100. Scoring is only based on correct answers.

(4) Investigation of learning attitudes toward the digital game

Based on the literature review, this study divides game design satisfaction into operational pattern and learning content. The digital game learning belief is divided into learning motivation and learning result. Based on these divisions, the researcher designed a draft of the "investigation of the learning attitude toward the digital game". After a revision by experts and experienced mathematics teachers, this investigation constructed expert validity. The investigation is based on a Likert 5-point scale with scoring from 5 to 1.

3.4. Data Analysis

For the quantitative processing, descriptive statistics, one-sample *t* test, paired sample *t* test and single factor covariance analysis, the researcher used SPSS 17.0. The qualitative data includes the teachers' class observations, reflections on the course and interviews with students. The researcher compared the qualitative with the quantitative data to discover the effects of different math learning environments on learning effectiveness and learning attitudes based on instruction in linear equations in two unknowns in junior high school.

4. Research Results

4.1. Learners pre-conditions

This study employed the t test for independent samples for the two groups' scores in the "pretest scale for linear equations in two unknowns pretest". The average score of the experimental group is 52.6786 and that of control group is 47.8966; the experimental group scores slightly higher than the control group. As for the equal variance, Levene's F=2.361 and p=0.130>0.05. This result assumes that the variance is equal and the test result t=0.955, p=0.344>0.05. Thus, it is inferred that the two groups' starting behavior is not significantly different.

4.2. Effect of the game-based e-learning model on the junior high school Grade 8 students' learning effectiveness for linear equations in two unknowns

The experimental group's paired sample t test for the pretest and posttest scores in the "scale of linear equations in two unknowns" has a significance of .004<.05, which is significant. Examining the means of the pretest and posttest, the experimental group's posttest is higher than the pretest. This result shows that with game-based e-learning, the experimental group's learning effectiveness is significantly enhanced, as shown in Table 4.

Table 4. Paired sample t test for the pretest and posttest scores of the experimental group

Tests	N=28 Difference of pair variance (pretest - posttest)						
	Mean	SD	Mean Deviation	SD	Mean SD	t	Sig. (two-tailed)
Pretest	52.68	17.02	-7.89	13.41	2.53	-3.12	.004**
Posttest	60.57	23.99					

**P<.05

To find the difference in the different groups' learning effectiveness, this study arranges 28 students in the experimental group according to their pretest scores (from top to bottom). The first and last 27% (8 students) are the high and low-achievement groups. The paired sample t test based the pretest and posttest scores is shown in Table 5.

Table 5. Paired-sample t test for the pretest and posttest scores of high- and low-achievement students in the experimental group

Groups	Tests	N=8 Difference of pair variance (pretest - posttest)						
		Mean	SD	Mean Deviation	SD	Mean SD	t	Sig. (two-tailed)
High-achievement group	Pretest	73.00	10.31	-9.38	7.84	2.77	-3.384	.012**
	Posttest	82.38	11.61					
Low-achievement group	Pretest	34.63	10.99	-4.00	9.80	3.46	-1.155	.286
	Posttest	38.63	18.11					

**P<.05

According to the results, the pretest and posttest for the high-achievement group has a significance of 0.012, which is significant. The mean of the posttest is higher than that of the pretest, demonstrating that through game-based e-learning, the high-achievement group's learning effectiveness is significant for linear equations in two unknown. The low-achievement group's significance for the pretest and posttest is 0.286, and it is insignificant. The effect of game-based e-learning on the low-achievement group students' learning effectiveness for linear equations in two unknowns is not significantly different. Therefore, instruction on linear equation in two unknowns using game-based e-learning more significantly enhances high-achievement students' learning effectiveness.

4.3. Difference for students experiencing "game-based e-learning" and "traditional instruction" in their learning effectiveness for linear equations in two unknowns

The significance of the paired sample t test for the control group's pretest and posttest scores in the "scale on linear equation in two unknowns" is .001, which is significant. According to the means for the pretest and posttest, the posttest is superior to the pretest. These results show that the control group's learning effectiveness is significant for linear equations in two unknowns through traditional learning, as shown in Table 6.

Table 6. Paired sample T test for the control group's pretest and posttest scores

Tests	N=29 Difference of pair variance (pretest --posttest)						
	Mean	SD	Mean Deviation	SD	Mean SD	t	Sig. (two-tailed)
retest	47.9	20.54	-7.59	11.18	2.08	-3.653	.001**
Posttest	55.48	23.26					

***P*<.05

This study analyzes the difference in the two groups' learning effectiveness for the different learning models. Group* pretest p value is .298, which is insignificant. This result means that the covariance (pretest score) and the dependent variable (posttest score) will not be different because there are different levels of independent variables. This result meets the assumption of regression coefficient homogeneity. A covariance analysis can be conducted, as shown in Table 7.

Table 7 Regression coefficient homogeneity test of scale on linear equations in two unknowns

Source of variance	SS	df	MS	F	Sig.
Regression coefficient homogeneity (group* pretest)	168.451	1	168.451	1.103	.298

Error item	8094.892	53	152.734		

**P<.05

According to single-factor univariate and covariance analysis, the between-group *F* value for linear equations in two unknowns is .000, *p*=.995, which is insignificant. This result means that without the effect of the pretest, the two groups of students are not significantly different in their posttest scores on linear equations in two unknowns. Hence, the learning effectiveness of game-based e-learning is not significantly different from that of traditional instruction, as shown in Table 8.

Table 8. Covariance analysis for the two groups' "scale of linear equation in two unknowns"

Source of variance	SS	df	MS	F	Sig.
Covariance (pretest)	22422.756	1	22422.756	143.530	.000**
Between-group (instructional methods)	.006	1	.006	.000	.995
Error	8263.343	54	153.025		

**P<.05

4.4. The effect of the game-based e-learning model on junior high school Grade 8 students' learning attitude.

This study analyzes the experimental group's scores for the "scale on learning attitude toward the digital game" and their performance in the experiment and probes into their learning attitude toward the digital game.

(1) Satisfaction with the digital game design of Math around the World

Using a one-sample t test, the researcher analyzed the operational pattern, learning content and total satisfaction of the experimental group. The results are significant, which means that the students are significantly satisfied with learning using "Math around the World", as shown in Table 9.

Table 9. T test on satisfaction with the digital game design of Math around the World

Dimensions	Test value =3					
	Number of Items	Frequency	Mean of Dimension	Mean of Single item	t	Sig. (two-tailed)
Operational pattern	6	28	23.5356	3.9226	6.897	.000**
Learning content	5	28	19.8215	3.9643	8.036	.000**
Total	11	28	43.3576	3.9416	7.990	.000**

**$P<.05$

For the operational pattern, the satisfaction with the "descriptions of rules" and "ease of use" is the highest. Satisfaction with "feedback from the game" and "interest" is the lowest. For the learning content, satisfaction with the "relevance of the course" and the "setting of learning objectives" is the highest. Satisfaction with the "selection of learning tools" and "difficulty of the content" is the lowest, as shown in Tables 10 and 11.

Table 10. One-sample *t* test for satisfaction with the game design of Math around the World: operational pattern

Items	Test value =3			
	M	t	df	Sig.
1. The interface of Math around the World is simple and easy to use.	4.0357	6.220	27	.000**
2. The rules for Math Around the World are simple.	4.2143	7.336	27	.000**
3. Math around the World provides sufficient clues to pass the stages	3.9643	5.533	27	.000**
4. The feedback from Math around the World encourages me.	3.7143	4.215	27	.000**
5. I obtain a sense of achievement by successfully passing the stages of Math around the World.	3.8929	4.584	27	.000**
6. The rules of Math around the World trigger my interest.	3.7143	4.033	27	.000**

**$P<.05$

Table 11. One-sample *t* test of satisfaction with the game design for Math around the World: learning content

Items	Test value =3			
	M	t	df	Sig.
1. The content of Math around the World is appropriate. It is not too difficult and not too easy.	3.7500	4.277	27	.000**
2. Through the design of Math around the World, I can learn linear equations in two unknowns in my mathematics course.	3.9643	6.088	27	.000**
3. The content of Math around the World is connected to my mathematics course.	4.2857	8.399	27	.000**
4. The learning objectives for each stage in Math around the World are clear.	4.0000	5.612	27	.000**
5. I am willing to recommend Math around the World to my classmates as a learning tool for linear equations in two unknowns.	3.8214	5.037	27	.000**

**$P<.05$

According to observation of the students' use of "Math around the World", most of the learners could finish the tasks using the instructions provided by the game without assistance. This result shows that the game design, in terms of the interface, instructions for the rules and the clues given for each task, provides specific information. The students much be active to be successful, and they actively search for assistance when they encounter obstacles. However, a few students realized that they could continue filling in the blank when they made mistakes. Their scores were not reduced by these mistakes and they were not punished. Hence, some low-achievement students tried to guess, which lowers learning effectiveness.

According to the interviews regarding students' learning after using "Math around the World", the students indicate that the game is not challenging because of the multiple choices and the lack of punishment. They suggest modifying the response mechanism. In addition, they suggest that a demonstration could be offered before the start of the game. Regarding the learning content, most of the students suggest that the first stages could be more difficult and the numbers could be simplified. In terms of the overall use, according to the students, it is interesting to learn mathematics using the game, and it also enhances their geographic knowledge. They suggest adding more questions and stages. Other units could also be practiced using game-based e-learning. Their suggestions are extracted as follows:

It is more challenging to restart after making mistakes. (S5)

Some questions are difficult and some can be guessed. (S12)

Please fill in the blank and avoid guessing the answers. Fill in one blank once and restart after making a mistake. (S17)

The third section of Math around the World is very difficult and it takes time to find the solution. (S15)

Stages 1 and 2 are basic and Stages 3 and 4 are extremely difficult. (S11)

Stage 1 is easy and it becomes more difficult at the following stages. (S6)

I hope that we can learn more units by games. (S3)

Although the calculation of some coordinates is difficult, it is helpful and we can learn coordinates of different countries around the world. (S8)

More games with different degrees of difficulty and questions can be added, and thus we can increase geographic knowledge by mathematics. (S14)

(2) Learning belief and the digital game

The experimental group's learning motivation, learning result and total belief are significant. Hence, the experimental group students have a positive and significant math learning belief after game-based e-learning, as shown in Table 12.

Table 12. *T* test of the digital game learning belief

Dimensions	Test value =3					
	Number of Items	Frequency	Mean of Dimension	Mean of Single Item	t	Sig.
Learning	7	28	26.7141	3.8163	5.678	.000**

motivation						
Learning result	10	28	37.7643	3.7643	6.904	.000**
Total score of learning belief	17	28	64.3569	3.7857	6.775	.000**

**P<.05

For learning motivation, satisfaction with the “intention to practice” and “pleasure” is the highest. The satisfaction with “math learning intention” and “attraction” is the lowest. For the learning result, satisfaction with the “application of knowledge obtained” and “identification with the learning method” is the highest. Satisfaction with Items 7 and 9 of “math learning confidence” are the lowest, and the results are insignificant. The reason for this result could be that some items are difficult. Students cannot solve them, and it lowers their math learning confidence, as shown in Tables 13 and 14.

Table 13. One-sample *t* test of digital game learning belief: learning motivation

Items	Test value =3			
	Mean	t	df	Sig.
1. Learning mathematics using the digital game triggers my interest.	3.7500	4.277	27	.000**
2. The design of stages in the digital game enhances the attraction of mathematics.	3.6429	3.315	27	.003**
3. Learning mathematics using the digital game enhances my concentration.	3.7500	4.104	27	.000**
4. Learning using the digital game enhances my math learning intention.	3.7143	3.873	27	.001**
5. I enjoy learning mathematics using the digital game, and I will practice more.	4.0000	6.148	27	.000**
6. In the future, if possible, I will learn math using digital games.	3.8571	5.091	27	.000**
7. I enjoy learning mathematics using the digital game.	4.0000	5.020	27	.000**

**P<.05

Table 14. One-sample *t* test of digital game learning belief: learning results

Items	Test value =3			
	Mean	t	df	Sig.
1. Through the digital game, I find math concepts that I should improve.	3.8571	5.645	27	.000**
2. By practicing the digital game, I learn more about linear equations in two unknowns.	3.6786	3.800	27	.001**
3. Through the digital game, I can apply math knowledge obtained previously.	4.1429	7.527	27	.000**
4. In the digital game, I obtain knowledge that is not related to linear equations in two unknowns.	3.7857	4.747	27	.000**

5. I can connect the content of the digital game with concepts I have learned before.	4.0714	7.398	27	.000**
6. I can apply the concept learned in the digital game to other courses.	3.7500	3.576	27	.001**
7. By learning using the digital game, mathematics is less difficult.	3.3214	1.800	27	.083
8. I obtain a sense of achievement by accomplishing the learning objectives of the digital game.	3.5000	3.000	27	.006**
9. I have confidence in learning mathematics knowledge through the digital game.	3.3929	1.834	27	.078
10. I am willing to recommend learning using a digital game to others as a math learning method.	4.1429	7.129	27	.000**

**P<.05

According to the analysis of the student interviews, there are many positive beliefs about game-based e-learning: it is new, more exciting than traditional learning, the learning stress is lower, it is based on cross-field learning, and there is continuous progress in the game, which constructs a sense of achievement in math learning. There were fewer negative beliefs: when learners cannot accomplish goals, their confidence is lowered, and the game images and question design can be improved to make the game will be more attractive and interesting.

The findings on satisfaction with the digital game matches the views of Wang et al. (2011) and Jou et al. (2008), who suggested that positive design elements in digital games are specific goals and rules, fair competition, appropriate challenges, high interaction and a balance between entertaining effects and learning objectives. As for the findings for the digital game learning belief, the learning motivation findings match the view of Pintrich (1989), who indicated that learning motivation will draw learners' attention. Learners will perceive a correlation between learning and value. The game meets the learners' expectation of success and emotional satisfaction. The learning result findings match Wu et al. (2006), who indicated that positive math learning methods can enhance math learning confidence, success attitudes, identification with the usefulness of mathematics and the enhancement of motivation to study mathematics.

4.5. Instructional process of game-based e-learning for linear equations in two unknowns

To find instruction of game-based e-learning and students' learning, the researcher collected the students' performance in class, the learning sheets, the digital game process and the teachers' reflection and modified the instructional process, as shown in Figures 15, 16, 17, and 18.

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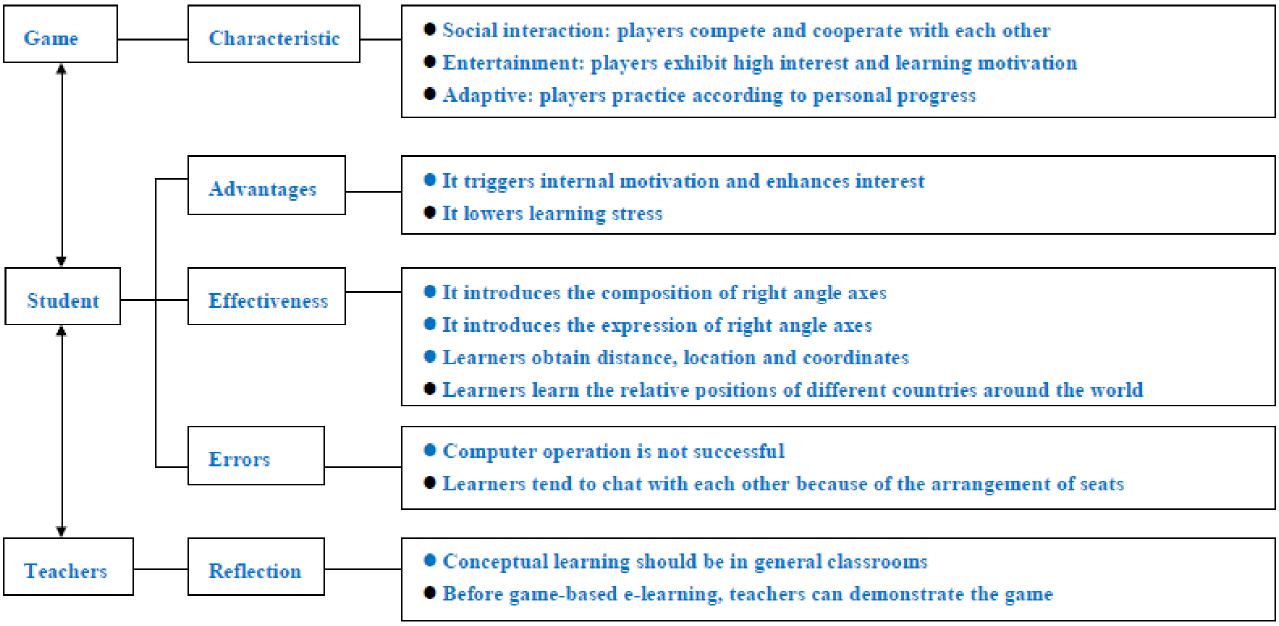

Figure 15. Experimental instruction analysis for Unit 1

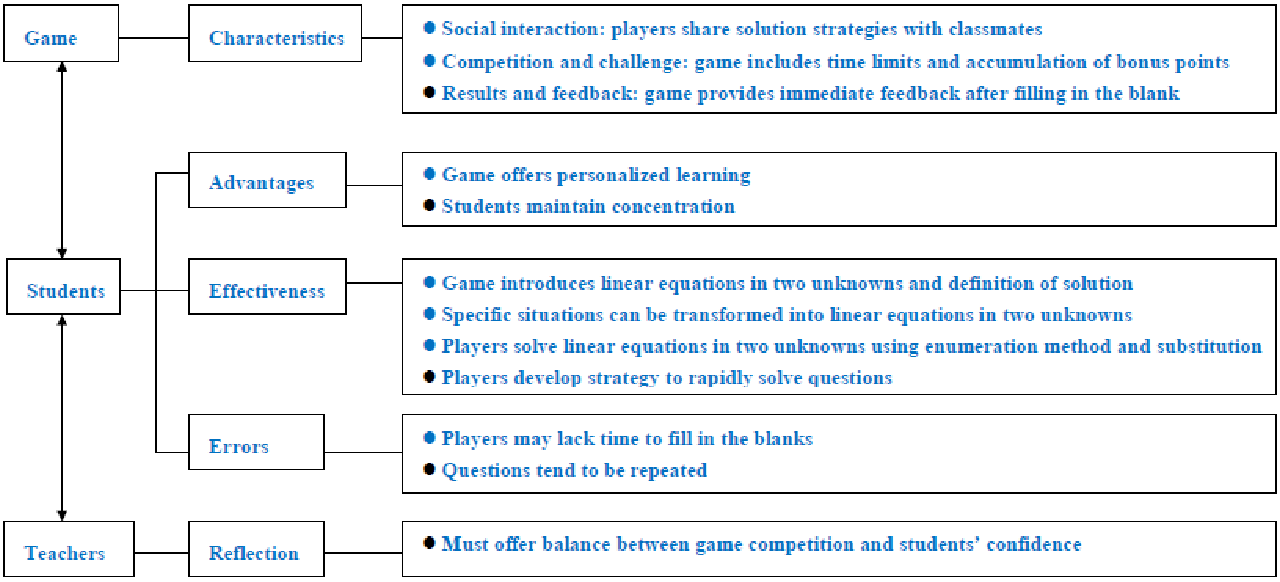

Figure 16. Experimental instruction analysis for Unit 2

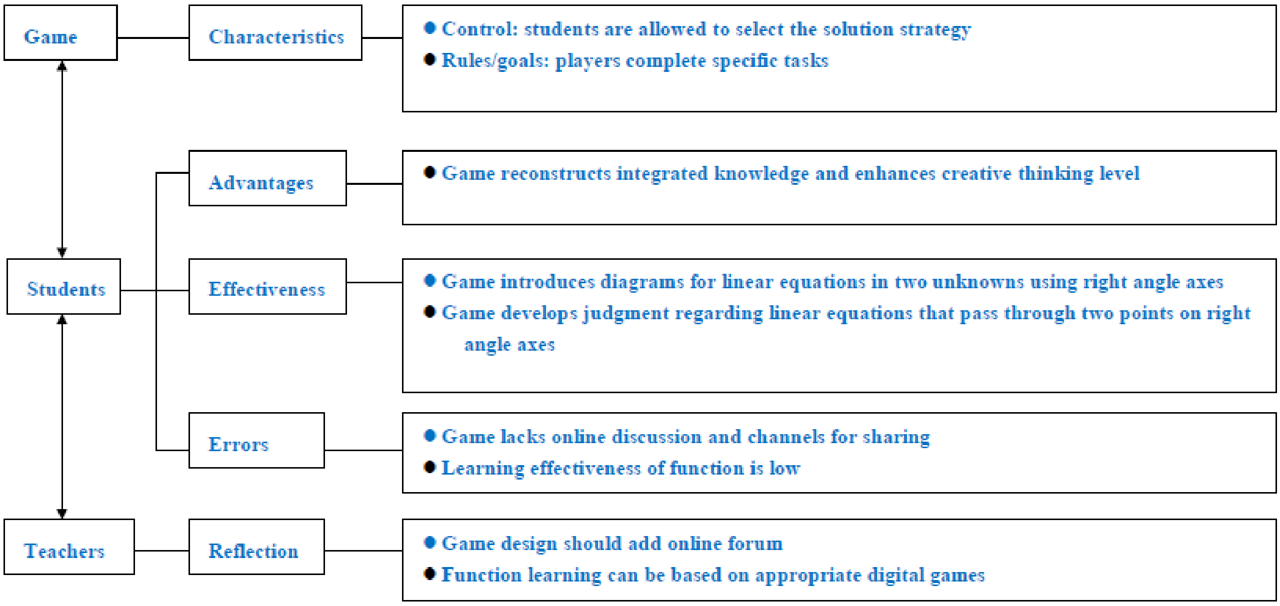

Figure 17. Experimental instruction analysis for Unit 3

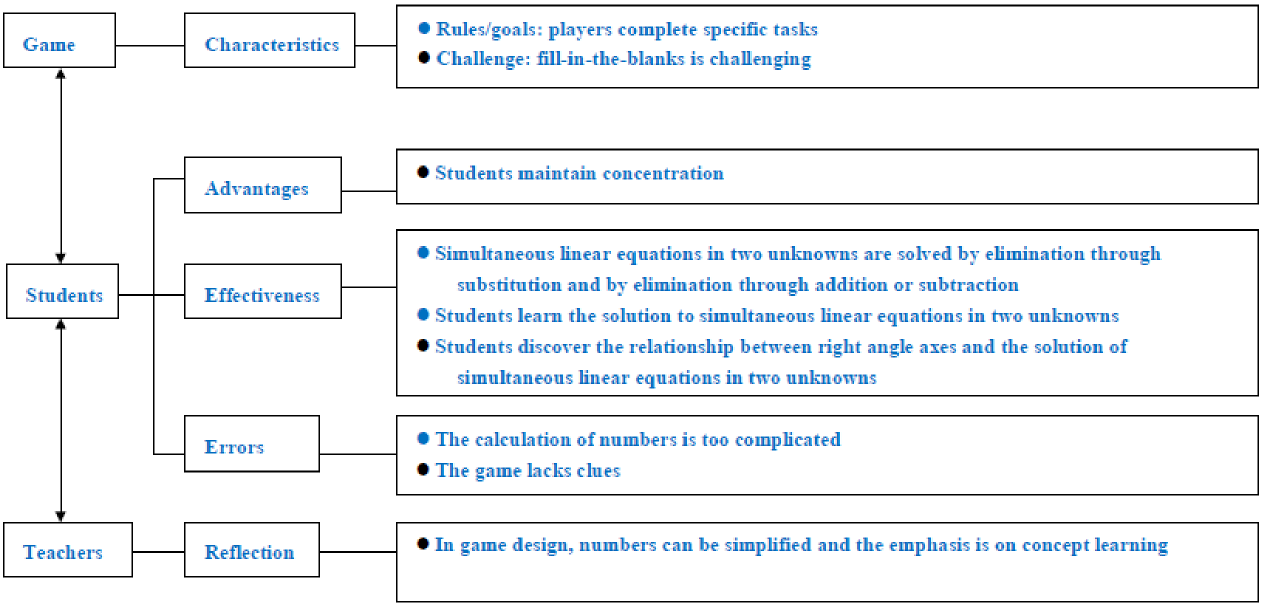

Figure 18. Experimental instruction analysis for Unit 4

As for learning effectiveness, game-based e-learning and traditional lecture instruction both demonstrate learning effectiveness. However, for learning motivation and belief, the game-based e-learning results are significant and positive in comparison to traditional instruction. Regarding game design, the students' discussions with others increase with the degree of difficulty. This finding shows the importance of user interactions. When students make mistakes in these types of digital game, is their learning performance influenced by the design of the punishment? This subject is worth further study. It is suggested that when designing the digital game, we add an interactive platform between the players and punish the players for wrong answers to more effectively enhance learning effectiveness.

Interesting animation and challenging designs for game-based e-learning meet the digital natives' preference. Therefore, the experimental group had positive mathematics learning motivation. Through exploration and the repeated practice in the digital game, the students are more familiar with what they have learned and they clarify their wrong cognitions. In the simulated situations, students not only accomplish their learning objectives, but they also learn other related knowledge.

5. Conclusion and Suggestions

5.1. Conclusion

(1) Game-based e-learning significantly enhances junior high school Grade 8 students' learning effectiveness when learning about linear equations in two unknowns.

Game-based e-learning significantly enhances learning effectiveness when learning about linear equations in two unknowns because the digital game provides an environment with high learning interest offering repeated practice. Through immediate feedback, the learners can modify their errors. The appropriate selection of a digital game for students' learning can enhance mathematics learning effectiveness. The progress of high-achieving students' learning effectiveness is the most significant. This progress demonstrates that the digital game provides an appropriate learning situation and that it encourages students to actively integrate various types of previously learned knowledge and seek for the best solution to enhance learning effectiveness.

(2) Students experiencing "game-based e-learning" and "traditional instruction" have higher and similar learning effectiveness when learning about linear equations in two unknowns.

Through game-based e-learning and traditional instruction, learners made significant progress in the pretest and posttest on linear equations in two unknowns: the two groups are similar. Hence, the students' learning effectiveness is not significantly different for these two types of learning, both of which can effectively accomplish instructional functions and learning goals.

(3) Game-based e-learning positively enhances junior high school Grade 8 students' learning attitude.

The "Math around the World" learners are satisfied with game-based learning. As for the game operation, the interface design is simple, and most of the students can play the game without reading the instructions. The positive rewards in the game encourage students to continue learning. Regarding the learning content, the digital game content matches the objectives of the instructional units. Hence, students have the intention to recommend the game to others. The group experiencing game-based e-learning had a positive math learning belief because the digital game triggers learning motivation through learning playfulness. The game guides students to complete the learning objectives of the units step by step. In the process, the students clarify their confusion. In the designed situations, the students obtain other knowledge. Because students are given a sense of achievement when they pass the stages, their learning confidence is considerably enhanced.

5.2. Suggestions

Some suggestions according to the findings of this study are made as follows:

(1) Suggestions for the design of the digital game:

i. Attractive interface that is easy to use: it should allow learners to successfully play the game with the least instruction. Hence, learners will concentrate on learning. Appealing images and sound effects can enhance the attraction of learning.

ii. Clear and specific rules and goals: with clear and simple rules, the game will be fair. With specific goals, learners are guided to learn the tasks.

iii. Design of an appropriate level of competition and challenge: competition can trigger learning motivations and maintain concentration. Appropriate challenges and an increasing level of difficulty can guide learners to overcome obstacles to accomplish their learning objectives.

iv. Complete planning of interaction and guidance: complete interaction should include human-computer interaction and player interaction. With positive human-computer interaction, the game can provide immediate feedback and clues according to the learners' selections to accomplish the tasks. Smooth interaction between players can supplement the learning guidance of the game and help teachers to discover the students' problems at the right time.

(2) Suggestions for digital game based instruction

Instruction should be based on a combination of traditional instruction and digital games. First, traditional instruction helps the students to construct basic concepts, and then they comprehend and learn the concepts using the digital game. The teachers should control students' learning at all times and find whether the game operation is successful. When students encounter difficulties, the teachers can provide clues to help them finish the task. The selection of digital games must be based on the fit between the game and the learning units. Hence, before instruction, teachers should properly design instruction to accomplish the best learning effectiveness.

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