Hayashi, Y., et al. (Eds.) (2017). Workshop Proceedings of the 25th International Conference on Computers in Education. New Zealand: Asia-Pacific Society for Computers in Education

A preliminary study of a digital game system to support mathematics learning: Using circle and compound shapes as an example

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Abstract: This study mainly focuses on building a digital game system to support learners to increase their learning motivations and achievements in mathematic learning. Through interviews with teachers and literature review, we found it difficult for students to learn about compound shapes. When students do not understand the relationship between circle and compound shapes, they may decrease their learning motivations and interests because of failing in advanced questions. For this problem, we selected this mathematical unit of "Circle and Compound Shapes" as an example for our study. Primary 6 class with 24 students who have studied this unit in Taiwan participated in a questionnaire survey as the requirement analysis for system development in this study. Based on the result of questionnaire, the game type of the system is adventure game. The design of scenario is an adaptation of a Taiwanese folk tale "Aunty Tigress" which is familiar to students. The contents are based on the van Hiele's geometric thinking level theory. Four game processes and bonus stage are designed in the courseware. This study is in stage of system development. We hope we can build a better game-based learning system by the result of questionnaire and game design to enhance students' knowledge and learning motivation of mathematics.

Keywords: e-Learning, Digital game-based learning, Mathematics learning, Circle, Compound Shapes.

1. Introduction

In the class of plane geometry, calculation of a circular area is the important competence indicator (Ministry of Education, 2008). Compound Shapes is hard to learn for elementary school students. They may use formulas directly without the understanding of compound shapes' composing. (Chen, & Wu, 2016). In order to realise these, we talked with an elementary school teacher. Students learn circle and compound shapes with difficulty. When they do exercises, they use the formulas of compound shapes to calculate. However, they don't realize how to use partition and combination in compound shapes. Hence, when solving advanced problems, they might fail or not understand and then affect their learning achievements. As well as the general teaching model, it usually by the teacher one-way teaching knowledge. It can't be adjusted according to the degrees of students. By teaching with paper for geometric abstract concept of graphics, such as the circular area and pi, students may not understand the association between them, and thus affect the follow-up unit or advanced knowledge of the circle.

In this study, the research questions:

- Through requirement analysis, what can we attribute to the direction of the system design?
- How to develop a digital game-based learning system with the mathematical unit of "Circle and Compound Shapes" to support learners learning?

In order to solve the above problems and discuss more proper teaching material design and method application, this research aims to develop a digital game-based learning system with circle and compound shapes. Let students manipulate graphics by digital devices to understand the

relationship of compound shapes and increase their learning motivations and achievements. This paper will explore the relevant literature, digital game-based learning system design and the results of need analysis.

2. Literature Review

2.1. Game-based learning

Owing to the rapid development of Internet and technology, digital games are popular now. Prensky (2001) expected to combine learning contents with digital games to make the same or better learning outcomes than traditional teaching. In recent years, Game-based learning has become an important research topic in learning (Cheng et al, 2013; Hsu, Tsai, &Wang, 2012). The game in Digital game-based learning is the evolution of e-learning. Now there are many scholars advocate digital game-based learning and hope to increase learning motivation and participation in this way. By game-based learning, we can live up to educate children while having fun with them at the same time and increase their learning achievement (Liang, Chen, Young, & Yang, 2008). And related research, Chen (2009) had used the game on teaching of addition and subtraction. She found that the experimental group had reached a significant level in mathematics learning; the traditional group didn't seriously answer questions. Learning in the game has many benefits and often near to the simulation of life experience more than traditional educational media (Chang, Tsai, Cheng, & Yu, 2016).

2.2. Mathematics learning

6th graders in elementary school are between the stage of concrete operational and formal operational in Piaget's Cognitive-developmental theory. They are about to start analogizing thinking and their abstract conceptions are building. Therefore, when students can't think logically, we should let them learn in the way of operation or other appropriate means (Lin, 2002; Hsu, 2013). Tseng (2002) mentioned that more than half of the students couldn't understand the compound shapes' concept of decomposing and composing in geometric graphics. It showed the difficulty in learning compound shapes.

Van Hiele (1986) proposed the geometric thinking level theory, divided into five levels, follows as visualization, analysis, informal deduction, formal deduction and rigor. These levels are sequential and from a level to the next level. Some related researches also pointed out different geometric concepts for learners may also develop different thinking levels and diverse learners will be at different levels (Wu, 1998；Golinskaia,1997；Poehl,1998；Swafford, Jones& Thornton, 1997). Therefore, this study is expected to improve students' understanding on compound shapes through digital devices and digital learning games, built on van Hiele's geometric thinking level theory.

2.3. Game-based learning in mathematics learning

We hope learners can increase learning motivations by learning in the game and also dilute the nature of the test, reduce learners' pressure to fit in with the concept in enjoyment (Cheng,2001). In the study of game-based learning games in mathematics learning, Wang (2008) developed a digital game-based courseware on cubic net called Happy Cuber to help learner establish mental rotation ability and the results showed this learning has a significant effect on low learning achievement students. Yeh, Yang, Liao and Lo (2016) designed a management game on primary mathematical course “Math Island”, so that students from one to sixth grades can learn from the management game on their own and the study found that can help students learn mathematics and improve students' learning motivations. Fan, Wang, Li and Wu (2016) build a game-based learning courseware on plane geometry “mi te play shapes”, based on van Hiele geometric thinking level theory and plane geometry that can help learners learn the concept of plane geometry. The results showed that a positive effect on the learner's plane geometry comprehension. In summary, digital game-based learning in mathematics learning is a practical way of learning. Not only increase students’ motivations, but also enhance their learning outcomes.

3. Methodology

In order to make sure that the game design and learning process are suitable for the study and the needs of the target users. This study adopted the questionnaire survey, including personal background, experience of game, mathematics learning situation and expectation of game.

3.1. Participants

We invited 24 elementary school students, 14 males and 10 females included. All of participants are between eleven to thirteen years old coming from the same school and class located in northern Taiwan.

3.2. Research design

The main research process has three stages, system development, research implementation and data analysis. In this study, we are in the stage of system development. For requirements analysis, we used quantitative questionnaires and qualitative answer questions.

3.3. Game Design

This game is based on Input-Process-Outcome Game Model to design the game framework, as shown in Figure 1. In the stage of "Input", we decided the mathematics unit-circle and compound shapes to be our contents through the questionnaires and discussion with the experts. Then, we read competence benchmarks of Grade 1-9 Curriculum Guidelines and current elementary matters for teaching in circle and compound shapes for reference to design the contents. In the stage of "Process", let learners into a fun and challenging situation to learn by the Taiwan folk tigress which people are familiar with it and we revised it. After the success or failure of the level, we will give the corresponding response to each other level, so that learners can keep learning through the game cycle. For high achievers and low achievers, they have corresponding design. For high achievers, after the completion of the levels, there will be additional levels to allow learners to continue learning. The additional levels are the calculations of compound shapes with difficulty. For low achievers, if they cannot move forward because of the failures, the game will provide the hints as feedbacks. Let low achievers to think how to clear the level by the hints so they won't decrease their motivations with the level difficulties increasing gradually. At the end, we expect that the learners will reach the learning aims by this study in the stage of "Outcome".

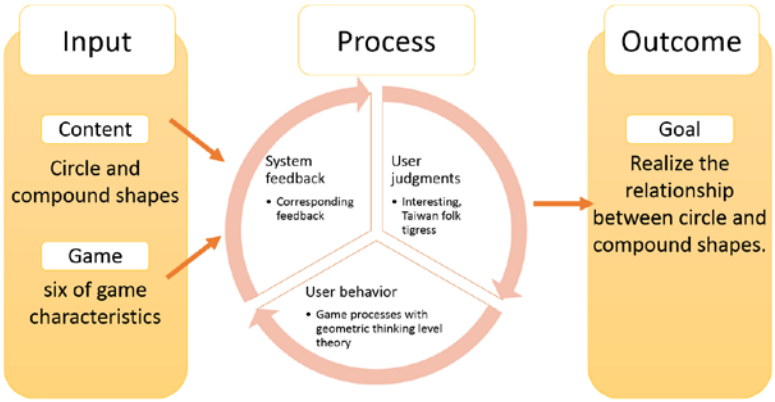

Figure 1. Game framework.

Based on Ausubel's meaningful learning theory, when the individual learning new concepts to form new knowledge will use their own pre-prepared concept to check the new concept and try to be included in the existing cognitive structure, so as to assimilate their own knowledge. In the design of the game scenario, we revised Aunty Tigress which are Taiwanese folk tales well-known in the daily

life and hope learners can through the existing knowledge, guiding learners into the learning status. Learners can incarnate into the brave of the game to help Aunty Tigress and compound shapes change into the objects of daily life to connect with existing experience enables learners have a fun and challenging learning environment to learn.

The design of the game content is based on van Hiele's geometric thinking level theory. Most of the 6th grades students are expected to be at levels between analysis and informal deduction, so we designed the game without levels of Formal Deduction and Rigor.

4. Results and Discussion

In the research stage of system development, we have a questionnaire survey. The following: personal background, experience of game, mathematics learning situation and expectation of game to analysis.

4.1. Personal background

For the personal background in questionnaire, we surveyed background of the objects. As a result, males accounted for 58.3% while females accounted for 41.7%. All of their ages are between eleven and thirteen. Their age who are twelve years old are the most.

4.2. Experience of game

This study aims to build a digital game-based learning system, so we conducted a survey about the experiences of games. As shown in Table 1, we listed Top3 of students' preferences toward game are adventure game, puzzle game, and quiz game. When we develop the game, we will characters of them to design. The main framework in the game is adventure game. We will add the elements of puzzle game and quiz game depending on circumstances in the game process.

Table 1: Students' preferences toward game (n=24)

Game type	Game example	number of people	Percentage
Adventure Game	Mario	11	45.8%
Puzzle game	Criminal case	11	45.8%
Quiz game	2048	11	45.8%

Then, we surveyed their habits when they play games. We found that up to 63% of the number of people don't want that their names are the main role of the game. Instead, they want to play from third person perspective. They think "collecting roles" and "having equipment" are the most engaging to keep playing. As a result, we made the brave instead learners' name. Learners can manipulate the brave from third-person perspective in the game design. In the game, we will design that many equipment will be collected by learners and different equipment have different functions.

4.3. Mathematics learning situation

To know which parts are hard for when learning circle and compound shapes, we had a survey with students who have learned this before. As shown in Table 2, this is a check-all-that-apply question. "The area and circumference of compound shapes" are harder to learn for students.

Table 2: Difficulty in mathematics (n=24)

Mathematics	number of people	Percentage
The area of compound shapes	9	37.5%
The circumference of compound shapes	9	37.5%
The circumference of sectors	6	25%

4.4. Expectation of game

This section examines students' exceptions and views of the game. We proposed two different types “drag to correspond graphics “and “draw graphics”. As shown in Table 3, we find two types of games are up to 75% of people willing to use to learn. Because of constraints on technical, we chose “drag to correspond graphics” for the game design. Only bonus level will have the function “draw graphics”.

Table 3: Two types of games (n=24)

	drag to correspond graphics		draw graphics	
	person	percentage)	person	percentage)
willing to use	20	83%	18	75%
Not willing to use	4	17%	6	25%

5. Conclusion

The result from questionnaires indicated that “the area of compound shapes” and “the circumference of compound shapes” are difficult to learn for learners. Therefore, the main learning content is compound shapes. In the game design, the game framework is based on adventure game. The operation of the game is third-person perspective. We hope learners can understand partition and combination of compound shapes through dragging corresponding graphics. This research is in the stage of system development now. We will follow the result to improve the game based on students' learning requirement and preferences as well as feedback. And then build a better digital learning game-based system. Finally, we truly expect when the system is completed, we provide multiple learning ways in learning mathematics.

Acknowledgements

This research was supported by the Ministry of Science and Technology, under the grant MOST-105-2511-S-007-002-MY3.

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