

## **Innovative design with learning reflexiveness for developing the Hamiltonian circuit learning games**

Meng-Chien Yang\*, Hsuan-Yu, Chiang

<sup>1</sup> *Department of Computer Sciences and Communication Engineering, Providence University, Taichung, 43301, Taiwan ROC*

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### **ABSTRACT**

*In this study, we use a new proposed framework to develop the Hamiltonian circuit learning games for college students. The framework is for enhancing learners' activities with learning reflexiveness. The design of these games is based on this framework to achieve the targeted learning outcomes. In recent years, the game-based learning is a very popular research topic. The Hamiltonian circuit is an important concepts for learning many computer science and electric engineering topics, such as IC design routing algorithm. The developed games use guiding rules to enable students to learn the Hamiltonian circuit in complicate graph problem. After the game, the learners are given a reviewing test which using the animation film for explaining the knowledge. This design concept is different from the previous studies. Through this new design, the outcome gets the better learning results under the effect of reflection. The students will have a deeper impression on the subject, and through self-learning and active thinking, in the game will have a deeper experience.*

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## **1. Introduction**

The study of the paper is the research of the game-based learning technology. The game-based learning is an emerging research topics of the learning technology. Developing a video game as a learning tool might include many different tasks and considerations. Basically, how the game can be effective for learning is the main concern problem. This problem can arouse many challenging research problems such as the learning model of the game, the foci of the game, the players' attitude of the game and the game development. Many studies focused on the game developments such as the development of a new gaming technology, the usefulness of the gaming tool proposed by the game company and the development process of the learning game. Other studies might focus on the effectiveness of the game such as the learning process, the learners' attitudes. Moreover, some complicate topics of the game industry such as the immersive experience of the players brought research interests. Traditionally, the game for learning the specific subject is regarded as the serious game. Many different serious games have developed for different purpose of training and learning. Although the serious games have

been used as the tool for education, most studies of the serious games remained on development of the functions of the game. Then how these games are effective and helpful for learning? This could be another challenging research topic. Our research goal is to find how to develop the effective learning method for game-based learning.

In this paper, a new framework for developing the learning game is proposed. Using advanced information technology, the design of digital games is booming in many applicable developments. Because of the unique interactive interesting and attractive features in digital games, it can arouse the students' interest in learning, and improve the willingness to learn a specific knowledge. However, students are less likely to think about the contents after the game, but keep playing down. Usually, it is until the final online evaluation begins to help the students to recall the contents of the previous. The process of the final review is important for the design. This will not only can immediately check whether the students have learned the knowledge, but also can let students have the chance through self-initiative to get the targeted knowledge. Based on the above consideration, this study proposes a new method for developing the game for learning by using the Role-Playing Game (RPG), chapters of textbooks and story development.

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\*Meng-Chien Yang, Department of Computer Sciences and Communication Engineering, Providence University. Email: [mcyang2@pu.edu.tw](mailto:mcyang2@pu.edu.tw)

In the beginning, we design the guiding rules to lead students to play the game. Suppose that there is a specific topic prepared for learning. The students are told to play the game linked to this topic. After the game, the learners are given a review test for enhancing the learning results. Meanwhile, we using a set of animation films to assist the learners. These films can be traced back to the pre-test which is given before the students play the game. Then, after the review test students will watch the related film with the content of the learning topic. This will strengthen the concept of knowledge link with the students in this topic.

In this paper, we use the above framework to design the game for learning an important subject: Hamiltonian circuit of the graph theory in discrete mathematics. The Hamiltonian circuit problem is to find an existing loop to visiting each vertex once on the graph. The Hamiltonian circuit problem is an important problem and can be applied to many different technological applications. To develop a game for learning the Hamiltonian circuit problem is an important problem both in computer science education and mathematical education.

In recent years, developing math games have become the popular research topic. The importance of mathematical games in mathematics education cannot be ignored. A practical approach of using the game for teaching math in the country junior high school was reported [1]. In addition, the author pointed out that the mathematical game teaching method has the following advantages and functions:

- (1) to stimulate students' interest and motivation to learn mathematics [2];
- (2) to help students from the specific experience to establish basic mathematical concepts and skills;
- (3) to cultivate students to solve the problem of flexible and deep reasoning thinking ability

In another paper [3], the experimental results and infield tests showed that the existence of mathematical games have considerable potential. Our paper follows these previous studies and will continue to explore the learning changes brought by this new design approach. Based on the hypothesis of the above research project, we hope our study of developing the game of the Hamiltonian circuit problem can help the students learning this problem. In our study, we had invited students who taking the course of the graph theory to play the game. The testing results showed our proposed framework can develop the effectiveness game to help student learning.

The remaining of this paper is organized as the follows. Section 2 discuss related studies of the game-based learning. Section 3 describe the design of our proposed framework. Section 4 is the description of the game development and system modules of the proposed game for the Hamiltonian circuit problem. Section 5 is the report of experimental results and discussion. The conclusions are put in Section 6.

## 2. Studies of Serious Game and Game-Based Learning

The research projects related to our study are the studies of the serious game. Based on the definition of the famous game design textbook, the serious games are those games for education and study, simulation, health and growth [4]. Serious game gives the [www.astesj.com](http://www.astesj.com)

players fun experiences and other explorations. Serious game design is built in the "fun" under the premise of the players in the process of the game, while achieving a sense of accomplishment, knowledge and training, and further use of the nature of media and entertainment to convey the effect of information and education [5][6]. A famous study argued that the practice of the serious game has the meaning of learning and is a systematic learning, so that students can learn from the experience of the game [7].

There are new studies that "video games" will be a very influential tool for learning [8][9]. Game-based learning is not a regular learning style but a revolution for education. It can increase the learner's motivation to learn and help learners to learn effectively to improve learning motivation and effectiveness. Learners playing the game, easily immerse into the game and the learning scenarios because of game challenges, level design or script story into the immersive state. Therefore, game learning can follow the experience of "heart flow" [10], a process to obtain the knowledge, so that learners immersed in the game. The theory of flow suggests that when learners are integrated into the task, they produce a state of mind that is isolated from the outside world. If students are in such a state of mind, students will have the highest motivation to learn.

The study of the serious game development could have many different aspects. Recently a reviewing paper [11] described some essential features of the serious games for education. In this paper, the authors stated that two major focus of the serious game are learners' attitude and game core mechanics. Another important study about how to use the serious game for collegiate computer science students is to use the game with course materials [12]. The development of the serious game might need the guidelines for design the game. A recent study [6] proposed the guidelines and stated the key factors of the serious game development. Based on the above studies, several factor could influence the design and implementation of the learning game. First, the connection between the learning materials and the learning game should be tight. Second, the development of the game should follow a guideline that can make the game to become a useful learning materials. Then, the third, the learning outcome should be evaluated with different and various considerations and assumptions. Based on these assumptions, our study focus on designing a new framework for developing the learning game. In this framework, we developed a new learning outcome called learning reflexiveness which can help the learners to enhance the learners' attitudes in the game-based learning process. The framework can help designer to develop the serious learning games.

## 3. Methodology and Framework of the Game Design

The design of our framework was initiated with the concepts of the flow simulation proposed by Csikszentmihalyi [10], [13]. When human are involve the activities with flow based on the theory proposed by Csikszentmihalyi, people can concentrate on these activities and have the immediate feedback. The flow simulation had been used the development of the playground and video games. The activities with flow can bring self-consciousness of awarding the related information and context. Based on this theoretical finding, we attempt developing the learning process with the game. We describe our design by the question what is a

good educational learning game? This will provide scaffolding for our proposed framework.

A good educational game can motivate the learners through the design of the presumptive learning situations. The presumptive learning situations are a set of conditional factors for identifying the initial condition of each learning level. The learning situation and RPG game scenarios are the main settings of the game. Meanwhile, in the domain of the game, the story narration is a factor that attracts the learners from being immersed in it. We create stories and game rules for the game. The learners follow the guideline proposed by [14] in the symbol of the code, through the code to show the navigation keys to read the story. The strategy of game design for each level should be in a gradually better mode that can help the learner to immerse into the story of the game. Following previous study, the game prepares easy, moderate and difficulty challenges to enhance the learners' self-esteem [15]. The design is to design a learning situation during learning low-challenge tasks to learning high-challenge tasks. We developed the setting of the game by adopting the concept of flow in different working environments.

We had study the game development for several years. We analyzed and found the following three motivational factors that help learners to play the games [16].

### 1. Challenge

Each game level can be design with a particularly challenge. The challenge will entice learners to continue the game. The design of challenges is to describe a clear game goal, then an uncertain outcome, and a related feedback. The different challenges can be design with different learning materials.

### 2. Curiosity

The interface on the screen and sound control can cause learners interest. The setting of the game world can be designed as an environment that the players can explore new items.

### 3. Fantasy

Fantasy environment is an important factor. It stimulates the intrinsic motivation of learners in two ways, one is to satisfy the learner's inner emotion, and the second is to meet the learners' cognitive needs, and to promote the learners to grasp the relationships in the game.

With these three factors, we add a new factor into the game development. The new factor is the reflexiveness of the learner. Once the learner is playing the game, the outcome and the challenges can help the learner to have the learning attitude to adjust the learning paths toward the meaningful goal. The reflexiveness for learning had been mentioned in the studies of mathematics education.

### 3.1. The Importance of Reflexiveness for Mathematics Learning

Reflexiveness mathematics learning refers to the fact that it is an effective way to learn mathematics through the reflection of the process of math learning activities. It is not only a general review or repetition of mathematics, but a deep understanding of mathematics activities involved in the knowledge, methods, ideas, and strategies and so on. The general operational mathematics is

based on "learning knowledge" as the main purpose, concerned about the current academic performance; reflexiveness mathematics is based on "learning to learn" for the purpose of focusing on the current academic performance and students' future development [17].

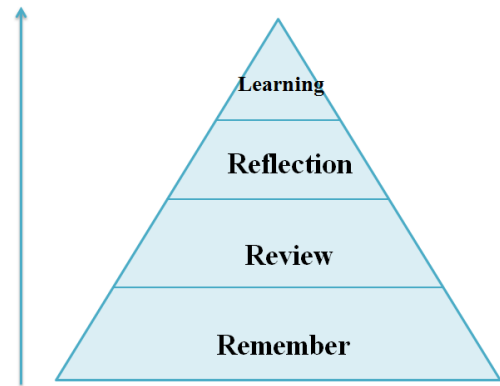


Figure 1: Reflectiveness of four learning levels

### 3.2. The reflexiveness in the proposed learning

Based on above discussions of the reflexiveness in mathematics learning, the reflexiveness can be applied to the other learning subject. The reflexiveness in the game-based learning can be illustrated as four different levels shown on Figure 1. The bottom level is the learning for remembering. This can be the basic of reflexiveness and are used as the fundamentals for accumulating knowledge. The second level is the learning with the reviewing content. The function of the second level is to enhance the effectiveness of the learning. The third is reflection which are the main level of our design. This level is to find the correct ways of learning the targeted subjects or courses. The final level is the effective learning process that the learners can successfully learn this subject.

We used the proposed framework to develop a game for learning the Hamiltonian circuit problem. The Hamiltonian circuit is an important graph in the graphic theory. The Hamiltonian circuit problem can be taught in the collegiate courses such as discrete mathematics, graph theory, combinatorial mathematics. The Hamiltonian circuit problem is an important concept in many computer science applications like logic design, routing problem. In next section, we describe our game that following the proposed framework.

## 4. Game Design and Game Play

In this section, the system design of the game is illustrated. At the beginning, the whole structure the game is to design with an RPG game structure combined with the fairy tale. Figure 2 shows the main menu of the game. The game is described as several chapters with different concepts of the Hamilton circuit. At the beginning of each chapter the learners will receive guidance rules. The guiding rules are put in a short RPG game and with a short introduction video clip. When the learner plays the RPG game, he can get the game rules. Using these rules, the learners can play and find the Hamilton circuit in a given graph (Figure 3). If the learner can successfully find the Hamilton circuit in the graph, the learner



can be guided to complete the chapter with more similar graphs. When the learners finish the chapter of the game, there is a chapter reviewing quiz which helps the learners to recall the process of gameplay. The learners can get an immediate feedback here and understand the correct answers which are the key terms of this chapter.



Figure 2 Main menu of the game

The reflexiveness setting in the whole scenario of the gameplay is a cyclic framework shown in Figure 4. In this framework, the learner can find the learning content in four different styles. The guide rules and the RPG game are used to attract the learner's attention. The game process is the main challenge and help the learner to understand the Hamilton circuit. The review test can help the learner to enhance the learning results. The teaching video can keep the learner's interest and go to next chapter which is more difficult Hamiltonian graph.

teaching film for the second time of reflective activities, the learners will have reflective experience based on the pasting activities.

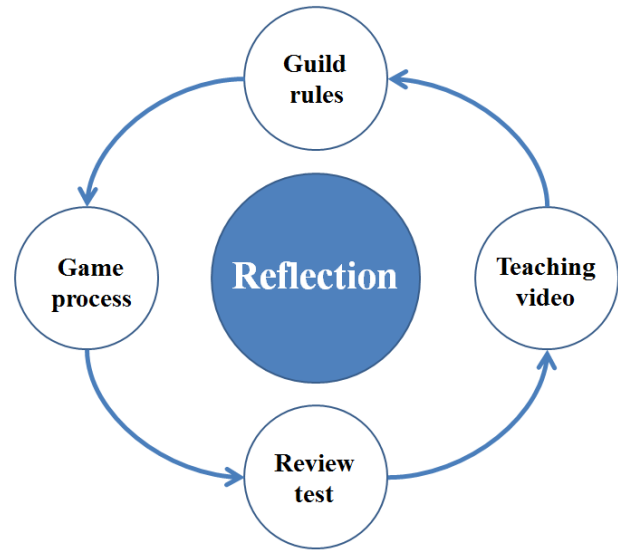


Figure 4: Game cycle that includes reflective learning.

The game is implemented with this system design. In the game, six cycles for the easy to complicate knowledge of the Hamilton circuit are implemented. After the review test, the learners can watch an animated film as the enhancement for learning reflection.

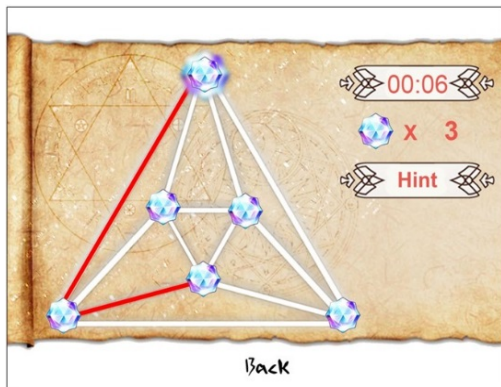


Figure 3: Gameplay for finding the Hamiltonian circuit

In addition, the reflective learning will affect the learners in two factors of each cycle. First, in the review of the test (Figure 5), learners need to recall the game experiences for answering these questions correctly. Second, the animated films with chapter concept guide, learners can link the game experience and answer process. An interesting design here is that the outcome of the story will vary depending on the score of the learner's game, which gives the learner the motivation to repeat the game.

Reflective learning should help the learners to get attention to the guidance and encouragement in the learning process. When the learners get the guide rules after the game, and in the review of the test to reflect on the game process and guide the rules of the tips, organize the answer to answer questions. When learners watch the



Figure 5: Screen shot of the online reviewing test

## 5. Implementation and Evaluation

The learning game was implemented and evaluated by a user-based evaluation and an expert-based working through evaluation. The approach was similar to a previous study of the educational serious game development [12]. A group of computer science major college students who taking the graph theory course were invited to participate the user-based evaluation. Our game was installed in a tablet computer and each participant was given 10 minutes to play the first three chapters of the game and then answered the quiz after the game. If the student could finish these three chapters successfully, the student would be given a big reviewing test and were asked to finish the remaining three chapters of the game.

The total number of students participating this experiment were 34. When the students finished the first three chapters of the

game, they were given a writing test for evaluating the basic concepts of the Hamiltonian circuit. When they finish the final chapter, the sixth chapter, the students were given a writing test with the complex knowledge of Hamiltonian circuits.

The experimental results showed 19 students had finished the first three chapters of the game and passed the basic test. Then, 15 students had finished the whole six chapters of the game and passed the advance test. Based on the evaluating, the developed game can be useful as a tool for teaching Hamiltonian circuit.

The second evaluation process is the expert walk-through test. We invited 8 computer major graduate students who had already understood the Hamiltonian circuit. When these students played the game, they were asked to find the shortcoming of the usability of the interface and evaluating the gameplay. Most students agreed that the game can help the beginner to learn the Hamiltonian circuit. Several mentioned the advanced part, the last three chapter should be improved with more illustration figures to help the learners play the games. Based on the suggestions, we are certain that the proposed framework can foster a comprehensive and effective learning.

## 6. Conclusion

In this paper, a framework for developing the learning games for advance computer science concept is proposed. In this framework, the learning process is arranged as a cycle with playing game, answering the review questions, watching the animation clips and being given the guiding rules. The framework is developed based on the concept of the flow and the fundamentals of the game theory. In addition, the reflexive review of the mathematical education is put in the framework and we coin a new learning attitude, reflexiveness. The reflexiveness design in the learning game can help the learners achieve the learning goal via playing.

We used this framework for developing the game for learning the comprehensive knowledge of Hamiltonian circuit. The results of evaluation showed that the game can help these participants to learn the Hamiltonian circuit. The game can be a useful teaching tool for courses related to graph theory and computer science. The game can be used for other purpose such that training course for novices to learn this concept at the IC design company.

The project has two successful results. First, we have develop a framework that can be useful as a guideline for other research studies who focus on developing the serious games for certain subject. Second, the game for teaching the Hamiltonian circuit can be useful as the teaching tool. In the next studies, we will explore and find more evidences that proposed framework is effective for the developing the serious learning game.

## Conflict of Interest

The authors declare no conflict of interest.

## Acknowledgment

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