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Incorporating Role-Playing Games into Programming Learning to Improve Computational Thinking

Yi-Hsing Chang[1], En-Chi Chang[1*], You-Te Lu[2]

[1]*Department of Information Management, Southern Taiwan University of Science and Technology, Taiwan*
[2]*Department of Information and Communication, Southern Taiwan University of Science and Technology, Taiwan*

yhchang@stust.edu.tw, ma790104@stust.edu.tw, yowder@stust.edu.tw

Abstract. This study integrated role-playing games into programming logic learning to improve learners' computational thinking abilities. The primary design idea was creating a game to use in a game-based learning model. Highly interactive puzzle adventure and escape room games were used in the game's scenes and stages, which can be completed by learners through computational thinking logic. The learning content and processes were planned according to elements of situated learning. The game-based learning content was based on the syntax and semantics of three control structures, namely sequence, selection, and loop. Comprehensive items were designed to help cultivate students' abilities in integrating these structures to solve problems. The participants were 27 students from a national industrial vocational senior high school in Kaohsiung, Taiwan. The students' scores before and after the learning sessions were compared using a t test to determine their learning effectiveness. In addition, a technology acceptance model questionnaire, which encompasses the dimensions of ease of use, usefulness, and enjoyment, was adopted to assess the students' intention to use game-based learning and their perceptions of the effectiveness of use. The results revealed that the difference between the student performance before and after the learning sessions was significant, suggesting that the developed game could be employed to enhance learning effectiveness. The level of improvement observed in the questionnaire dimensions was also significant. Therefore, the role-playing game developed in the present study was verified to improve learners' computational thinking and learning effectiveness.

Keywords: Role-playing game, technology acceptance model, programming language, computational thinking, game-based learning

1. Introduction

On December 10, 2015, Barack Obama, the then president of the United States, signed the Every Student Succeeds Act, which officially includes computer science in primary education. The current Chief Executive Officer of Apple Inc., Tim Cook, opined in 2017 that governments across the world should incorporate programming into education. In August 2018, the Taiwanese government revised the Curriculum Guidelines of 12-Year Basic Education to include information technology in the basic curricula with the aims of promoting the early implementation of basic education regarding information technology and enhancing Taiwanese people's abilities related to computational thinking and problem-solving, collaborative and creative computing, and presenting and communicating about computing, among other abilities [1].

In traditional programming education and training, the goal is to train qualified engineers. However, since programming has been incorporated into basic education, fostering the development of future engineers is no longer the sole goal. Linn and Dalley (1985) indicated that learning programming not only facilitates an understanding of programming methods but also enables the comprehension of problem-solving methods, which can then be applied in other fields [2]. Mayer (1986) reported that after students learn programming, they exhibit superior performance in problem transfer and understanding abilities [3]. Duke et al. (2000) asserted that learning programming can develop students' problem-solving and advanced thinking abilities, which can positively affect their subsequent careers [4].

Several problems emerge when students attempt to learn programming. Manni et al. (2006) indicated that learning programming language is challenging. Faced with a complicated and bulky architecture, comprehending the essence of programming through self-learning is difficult for beginners [5]. Davies (1993) mentioned that learning programming involves learning the syntax, semantics, and writing of the programming language [6]. In addition, debugging requires adequate patience, perseverance, and experience. Traditional programming teaching methods focus on syntax. Beginners often use mixed-up programming structures because of misunderstandings and fall into cycles of repeated errors, which easily makes learners feel overwhelmed and depressed [7][8]. Traditional programming education overly emphasizes knowledge transmission while neglecting the process of knowledge internalization [9].

Game-based learning is a variant of teaching combined with games to improve students' learning motivation and interest. In other words, many scholars have reported that games with educational goals and curricula can enable learner-centered teaching to be implemented in a more relaxed, enjoyable, interesting, and effective manner. For example, Lampropoulos & Sidiropoulos (2024) conducted a long-term study on online, traditional, and gamified learning environments [10]. The results indicated that gamified learning enhances student engagement and academic performance.

This study used the technology acceptance model (TAM) to explore the effectiveness of role-playing game (RPG)-based learning in computational thinking education. The goal was to enable the learners to improve their learning motivations and learning effectiveness after engaging with the programming-related game. The research objectives were as follows:

(1) Understand the effects of students' use of game-based learning on their perceived ease of use, perceived usefulness, and perceived enjoyment
(2) Understand whether perceived ease of use, perceived usefulness, and perceived enjoyment affect students' intention to use game-based learning
(3) Understand whether variations in students' intention to use game-based learning affect the effectiveness of using game-based learning

2. Literature Review

2.1. Game-Based Learning Theories and Applications

Computer games play an essential part in contemporary social and cultural environments. Numerous scholars have opined that games encompassing educational goals and curricula enable learner-centered teaching to be implemented through more relaxed, enjoyable, interesting, and effective methods. Quinn (2013) explained that games create a context that stimulates intrinsic motivation and enjoyment and improves comprehensibility and thinking during the latent cognitive process [11]. In play-oriented teaching methods, computer games can arouse students' learning motivations by presenting a challenge, a novel scenario that arouses curiosity, and a fantastic world. Prensky (2001) indicated that game-based learning has the characteristics of being a form of fun, being a form of play, having rules, having goals, being interactive, providing outcomes and feedback, being adaptive, having a win/lose scenario, having conflict, competition, and a challenge, having problem-solving, having interaction, and having representation and a story [12]. Specifically, games are potentially a powerful learning environment for the following reasons [13]: Games provide multisensorial environments for active, experiential, and problem-oriented learning. Games facilitate the absorption of knowledge because players must challenge the stages based on their accumulated knowledge. Games provide immediate feedback, allowing players to verify their hypotheses and learn from their actions. Games enable learners' self-evaluation through the mechanism of scoring and stage challenges. Through games, numerous players form social environments.

The design of games for learning mostly involves the use of modular theory as the framework to improve the flow of game content. Garris et al. (2002) proposed an input–process–outcome game model to divide the architecture of a game design module into three steps [14]. First, input refers to the design of the input of game-based teaching material content, which combines instructional content and game characteristics. Second, process involves user-oriented processing and includes a game cycle of user judgments, user behavior, and system feedback. After learners complete their learning, this cycle provides a debriefing that integrates the instructional content and game characteristics combined in the first step. Finally, outcome refers to the learning outcomes achieved through the game cycle. The game cycle module is shown in Fig. 1.

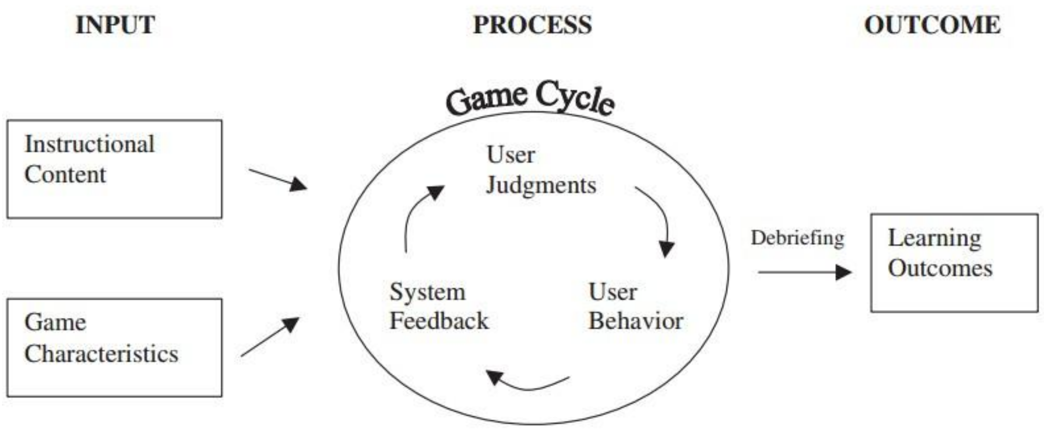


Figure 1. Module of Game Cycle

Regarding game-based learning applications, Cardinot & Fairfield (2019) developed a novel board game for learning astronomy and investigated how this game could be used to promote the learning and teaching of astronomy themes covered in the new science curriculum in Ireland [15]. The results verified that the game is a useful learning tool and an activity that promotes social skills. Hooshyar et al. (2021) proposed an adaptive educational computer game named AutoThinking to develop students' computational thinking skills and their conceptual knowledge [16]. The results revealed that learning by playing an adaptive educational game could significantly improve students' computational thinking related to conceptual knowledge and skills. Morelock and Matusovich (2017) conducted an experiment and reported that game-based learning methods give students autonomy [17]. The participating students could manage and employ various materials in interactions during the learning time.

Instructors' lectures are another focus. Although instructors share game-based teaching models with each other, such models differ greatly from nondigital game-based lectures. Sung and Hwang (2013) developed a collaborative game-based learning environment by integrating a Mindtool to facilitate students sharing and organizing what they learned during the game-playing process [18]. The experimental results revealed that the environment promoted students' learning attitudes and learning motivation while increasing the students' learning achievement and self-efficacy. Hess and Gunter (2013) explored the learning effectiveness of game-based courses and traditional courses [19]. The experimental results demonstrated that game-based courses resulted in significantly greater student learning effectiveness and learning motivation, as well as lower learning obstacles, compared with traditional courses. Generalized goals not only promote the accomplishment of courses but also enhance students' preservation and comprehension of course materials. Abdool et al. (2017) concluded that when students are encouraged to learn course contents with themes related to programming and software through gamification, their learning interest is sparked, thereby encouraging them to participate and implement course content [20]. Accordingly, the students increase their understanding of relevant techniques.

2.2. RPGs

RPGs involve players controlling or acting as a main character in a game. RPGs take place in narrative-driven worlds. Players navigate through maps in the game to collect items or complete story-related tasks in order to obtain special items or equipment to improve their abilities. Digital RPGs involve the transfer of RPG platforms to video game consoles and the establishment of a virtual world in which players manipulate the main characters to experience the game. During the gaming process, players can control the main characters and multiple members of their adventure team to execute solo or multiparty tasks. Therefore, RPGs involve story elements, promote player character growth through story plots, and portray a complex, playful, and immersive world of game.

Regarding the application of RPGs in programming learning, Mochammad et al. (2022) mentioned integrating information and communication technology in learning media to add fun, innovation, and enjoyment to students' learning activities [21]. They developed an educational game with an RPG mechanism for basic courses. The results of various verifications and tests revealed that implementation of RPG-based learning media is highly feasible and effective for learning activities. Silva et al. (2021) reported that university students often lack learning motivation to complete tasks, including logical reasoning and algorithm design in programming-related courses [22]. This suggests that learning programming is difficult. Thus, the present study aimed to use a 2D point-and-click RPG based on a traditional source code to provide basic instruction regarding programming. The experimental results confirmed that the game was well-received by the users and realized the goal of creating an interesting, useful, and effective method of learning the Python programming language. Li and Edwards (2020) described how to adequately apply RPG elements (e.g., levels, experience points, and personality traits) in programming activities [23]. Gamification elements can be strategically constructed by providing feedback on time management behavior, increasing software development practices, and prompting continual self-examination regarding personal efforts, thereby enhancing concrete student practice and working habits. Silva et al. (2020) proposed an RPG for learning programming logic-related concepts through methods such as scroll and item collection and task execution [24]. A total of 19 learners were recruited for the experiment. The results revealed that the students had a satisfactory experience in the gaming process, which positively affected their learning. Silva and Silveira (2020) conducted a systematic review of open educational games designed for instructing computer programming and computational logic [25]. The authors concluded that most of the literature recommends using component-based development, reuse, and adaptation in game design; however, reuse still does not occur in practice. In addition, the number of studies regarding educational games in programming teaching is low.

According to the literature, most scholars acknowledge that using RPG-based learning can improve students' learning motivation and learning effectiveness.

2.3. TAM

The TAM is a behavioral thinking model proposed by Davis (1986) based on the theory of reasoned action [26][27][28]. This model was designed to enable users to accept new information systems. When users begin to accept new information systems relating to computer technologies, the TAM can be used to explain user behavioral patterns. The goal is to identify effective behavioral patterns and analyze the factors that affect user acceptance.

Researchers applying the TAM use perceived usefulness and perceived ease of use as the independent variables and attitude, behavioral intention, and actual use as dependent variables to understand the effect of external factors on users' internal beliefs, use attitude, and behavioral intention and the subsequent effect of these on the use of information technology. According to the TAM, when users begin to use a new technology, many factors may affect users' efficiency and difficulty in using the technology.

The TAM is most frequently used as a model to evaluate emerging technologies. For example, Vahdat et al. (2020) used the TAM to assess customers' intention to purchase mobile application programs [29]. Fussell and Truong (2021) developed an extended TAM, which included factors related to the use of virtual reality technology in education and training environments [30]. Abundant studies have explored the TAM and social media acceptance; however, no study has adopted the TAM to understand the factors that affect the adoption of social media in higher education. Al-Qaysi et al. (2021) collected 539 articles, of which 59 were included in the analysis phase to identify the primary factors influencing the adoption of social media in higher education institutions [31]; the results revealed that "perceived enjoyment," "subjective norm," "self-efficacy," "perceived playfulness," "perceived critical mass," and "openness" were the most frequently cited factors. Understanding these factors helps decision-makers at such institutions make wise decisions regarding the use of social media platforms.

3. Methodology

3.1. Research Architecture

The main objective of the present study was to apply RPG-based learning in programming logic to explore students' learning effectiveness and intention to use the proposed learning method as well as to identify relevant factors. Thus, the research framework used the TAM as the basis and included six dimensions: RPG-based learning, perceived ease of use, perceived usefulness, perceived enjoyment, intention to use RPG-based learning, and effectiveness of using RPG-based learning.

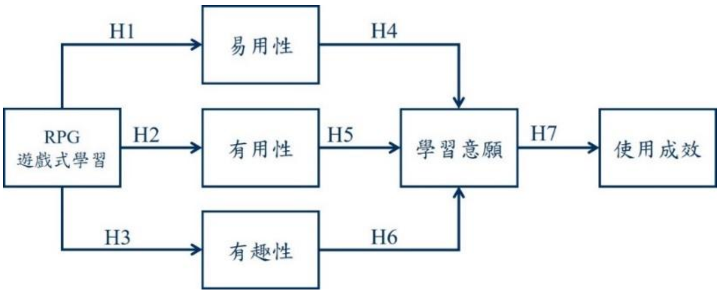


Figure 2. Research Framework

Based on the framework, seven hypotheses were proposed:

H1: RPG-based learning has a positive effect on perceived ease of use.

H2: RPG-based learning has a positive effect on perceived usefulness.

H3: RPG-based learning has a positive effect on perceived enjoyment.

H4: Perceived ease of use has a positive effect on intention to use RPG-based learning.

H5: Perceived usefulness has a positive effect on intention to use RPG-based learning.

H6: Perceived enjoyment has a positive effect on intention to use RPG-based learning.

H7: The intention to use RPG-based learning has a positive effect on effectiveness of use.

3.2. Procedure and Mechanism of Game Design and Creation

Computational thinking mainly involves the cultivation of problem-solving abilities based on sequence, selection, and loop structures. Thus, "if," "if else," and "switch" syntaxes and semantics were introduced for the selection structure. The syntaxes and semantics of "for," "while," and "do while" were introduced for the loop structure to improve learners' computational thinking.

The learning model proposed by Garris et al. (2002) was employed to design a computational thinking RPG (CT_RPG) [14]. During the input step, teaching content was combined with game characteristics.

In the process step, these functions were entered into a game cycle, which included user judgments or responses and user behavior to further obtain system feedback. In the output step, feedback on learning outcomes was obtained. We designed three maps with two, two, and one stage, respectively. The learners were required to learn the contents sequentially and pass the five stages.

3.2.1. Game Design Concepts

The game design concept originated from puzzle adventure games and escape room games. Both games are popular types of puzzle games. In addition to high interactivity, the games are suitable for use as the media for game-based learning.

(1) Puzzle adventure games: Players analyze the provided clues, items, and other information and interact with various objects in the game. Various items or mechanics match with each other according to gaming mechanisms. Players explore intricate traces in the game to understand the story, unveil the answers to the puzzles, and complete stages.

(2) Escape room games: Players are placed in a completely closed location. Players are required to search for items and clues associated with game mechanics. The games include puzzles. Players use the found items to interact with various game mechanics to complete assigned tasks. The goal is to escape the space. This type of game is also categorized as a puzzle adventure game. Escape room games are employed as the theme of some movies.

3.2.2. Story

The story begins in the daily life of a student who wakes up in the morning and is ready to go to school. The student encounters stages such as homework and tests. To increase the puzzle elements and interactions in the game, many challenges are posed in the story for players to challenge sequentially. Various escape room mechanics and puzzles are presented in the stages.

The first room features an escape room game design. When the protagonist is about to go to school, he finds himself locked in the room. To go to school, the protagonist must think of a way to get out of the room. After the player uses the computer to control the cat to move inside the room, the room key can be found in the cat's mouth. Then, the player can leave the room and go to school.

After the character sits on the seat at school, another story begins. The teacher first enters the classroom to collect homework. The player's task is to collect scattered homework pieces and turn them in. Later, the teacher asks the character to sort the homework by score. After sorting, the player may manipulate the character to leave the classroom and go to the teacher.

After leaving the classroom, the character is transported to a strange place. The teacher appears from nowhere and asks if the player completed the homework. Then, the player enters the final stage and must answer questions in the homework. The questions correspond to material presented in prior stages. After completing all questions, the protagonist wakes up and realizes that it was just a dream. Then, the protagonist goes to school as usual.

3.2.3. Game Maps

Four maps were designed for the game, as shown in Fig. 3.

Figure 3. Maps for CT_RPG

(1) First map (top left): The protagonist's room, which is divided into two blocks: inside and outside the room.

- Inside the room is the bedroom. The items within the room are a student ID card and a computer. Activating the computer can manipulate the cat in the living room.
- Outside the room is the living room. In addition to the furniture and ornaments, the most important object is the cat character. When the player manipulates the cat and moves it to a designated point, the cat jumps into the room. When the player chats with the cat, the player can obtain the room key and move outside the room. After the player obtains the key, the cat moves freely.

(2) The second map (top right): The computer classroom is used the design basis. The main interactive objects include several classmates and the protagonist's seat. When the protagonist sits on the seat, the following story and stage begin. First, the protagonist needs to collect homework pieces, which are originally hidden on the map and only displayed after the stage starts. Among the homework pieces, correct and blank ones appear. When players interact with the blank ones, the number of homework pieces does not increase. After collecting all homework pieces, the player can chat with the teacher and turn them in. The teacher confirms whether the number of homework pieces is correct. If it is not, the teacher asks the player to continue to collect homework pieces.

(3) The third map (lower left): The stage resembles the design of a final boss stage in a fantastic RPG. However, most of the content in the map is simply conversations. Once the player enters the map, the story begins automatically and proceeds to the final answering stage. After the stage is completed, the protagonist is automatically transported to the end map. Thus, no interactive objects were integrated into the map.

(4) The last story end map (lower right): This map was designed based on the first map. However, the frame is narrower to demonstrate the difference between a dream and reality. The layout of various objects is not as beautiful as in the dreamworld shown in the first map. When the player enters this map, the concluding story conversation begins. Then, the ending credits

acknowledging the player and the end scene of the game are displayed.

3.2.4. Game Stages

For five computational thinking logic tasks, we designed corresponding game stages and a comprehensive stage to evaluate whether the learners' computational thinking abilities improve after RPG-based learning. The game stage design featured the following:

- Use of situated methods to allow interaction between learners and the game
- Use of interaction and game feedback to enable learners to learn relevant computational logic
- Instructions given in each stage to help the learners review

Relevant instructions for each stage are as follows.

(1) Stage 1: "if and if else"

At the beginning of the game, the protagonist wakes up and wants to go to school. However, the door of the room is locked. The player must search for the door key. The stage is designed with the if conditional judgment. The player must collect the student ID card to use the computer. After interacting with an object, a prompt is displayed to inquire what action the player wants to be done. All actions are implemented according to the if conditional judgment, as shown in Fig. 4.

Collect student ID card　　　　Interact with an object

Figure 4. Diagram of "if" Conditional Judgment

(2) Stage 2: "for"

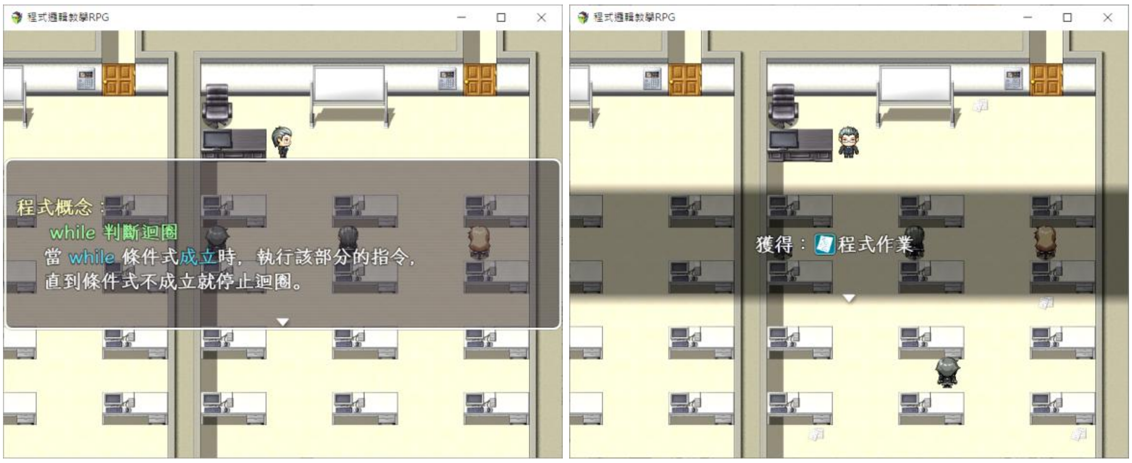
After completing the if conditional judgment stage, the player successfully activates the computer, and the instructions for this stage appear. The player needs to control the cat to move to the designated area. The player needs to specify the moving direction and enter the required number of steps to guide the cat to the designated point. A counter is shown to indicate the remaining steps. After the cat successfully arrives at the point, the player can chat with the cat to obtain the room key, as shown in Fig. 5.

※Input moving directions and number of steps ※Moving directions and number of steps

Figure 5. Diagram of “1for” Loop Stage

(3) Stage 3: “while”

After leaving the room, the player enters the next map. The stage requires the player to collect five homework pieces and provides a tip that the programming expression of the action is while (n < 5). At first, the player does not have any homework (n = 0). When the player begins to collect homework pieces, each piece collected renders n = n + 1 until five pieces are collected (n = 5). The condition of while(n < 5) is rejected, and the loop ends. The player completes the stage by turning in the homework pieces as required, as shown in Fig. 6.



(1) Instructions of the stage (2) Collect designated items for the task

Figure 6. Diagram of “while” Loop Stage

(4) Stage 4: “switch”

The design content of the stage involves the switch conditional judgment. The rule is to sort homework pieces according to scores. At the beginning of the stage, the player is provided with a grade score comparison chart. The total number of items is designed to be 10. Each item exhibits a random score (grade) that the player must sort. After 10 items are completed, the accuracy of sorting is displayed, as shown in Fig. 7.

(1) Stage instructions (2) Stage process

Figure 7. Diagram of Stage for “switch” Conditional Judgment

(5) Map 3 and Stage 5: Comprehensive Test

Stage instructions: Fig. 8 shows the final stage. The programming concepts employed in all previous stages are presented in the form of multiple-choice questions. The questions inquire into the programming concepts suitable for each of the various situations. Then, the number of items answered correctly is calculated, and a corresponding rating is given.

(1) Question (2)Answer

Figure 8. Diagram of Comprehensive Test Stages

4. Experiments and Results

Before using CT-RPG for learning, the participants completed a pretest. After the learning, they took a posttest and completed a questionnaire.

4.1. Participants and Gaming Experience

The participants of the present study were 27 students from National Kangshan Agricultural and Industrial Vocational Senior High School in Kaohsiung, Taiwan. Distance education was adopted during the COVID-19 pandemic period. The research team uploaded CT_RPG onto a web server; the students used their personal digital devices to operate the game and complete the questionnaire. A digital questionnaire was employed as the administration platform. All the students possessed experience in using digital games. Among them, six had experience in playing RPGs, six had experience in using game-based learning, and only two had experience in using RPG-based learning. A total of 27 questionnaire responses were collected. The gender distribution of the participants was 9 men and 18 women. The distribution of the students' year of study was 5 first-year students, 10 second-year students, and 12 third-year students.

4.2. Analysis of Learning Effectiveness

The study recorded the students' pretest and posttest scores and used a paired-samples *t* test to analyze their learning effectiveness. The results are shown in Table 1. The pretest mean score was 3.370 points, whereas the posttest mean score was 4.222 points. The pretest and posttest standard deviations were 1.334 and 1.552 points, respectively. The results of the paired-samples *t* test for comparing the pretest and posttest scores are shown in Table 1. The *p* value of the difference between the pretest and posttest scores was .025 ($p < .05$), suggesting a significant difference between the pretest and posttest scores.

Table 1. Statistics of Students' Pretest and Posttest Scores

	M	N	*SD*	Standard error of mean
Pretest score	3.370	27	1.334	.256
Posttest score	4.222	27	1.552	.298

p < .05

4.3. Statistical Analysis of Questionnaire

The analysis of RPG-based learning is shown in Table 2. The mean of the dimension was 3.7 points. Item Gbl3 exhibited the highest score of 3.90 points, indicating that the participants enjoyed using the proposed game for learning.

Table 1. ***RPG-Based Learning***

Number	Item content	*M*	*SD*
Gbl1	CT_PRG is easy to operate.	3.60	.699
Gbl2	CT_PRG is helpful for learning computational thinking.	3.60	.516
Gbl3	Learning through CT_PRG is interesting.	3.90	.737
Mean		3.7	

The analysis results for perceived ease of use are shown in Table 3. Item Peou5R was a reverse-coded item. The score of the item was counted in a reverse manner before analysis. Higher scores indicated greater perceived ease of use. The mean of this dimension was 3.56 points. Items Peou2 and Peou3 had the highest score at 3.70 points.

Table 2. Descriptive Analysis of Perceived Ease of Use

Number	Item content	*M*	*SD*
Peou1	Learning through CT_PRG is easy.	3.40	.843
Peou2	CT_PRG is easy to use.	3.70	.674
Peou3	CT_PRG is easy to understand.	3.70	.483
Peou4	I enter the learning state soon when learning through CT_PRG.	3.60	.699
Peou5R	CT_PRG cannot make learning easier.	3.40	.966
Mean		3.56	

The results of the analysis of perceived usefulness are shown in Table 4. Item Pu6R was a reverse-coded item. The overall mean of the dimension was 3.68 points. Item Pu3 had the highest score of 3.80 points.

Table 3. Descriptive Analysis of Perceived Usefulness

Number	Item content	*M*	*SD*
Pu1	Learning through CT_RPG is helpful for my score.	3.70	.675
Pu2	Learning through CT_RPG helps me understand course highlights more rapidly.	3.70	.675
Pu3	Learning through CT_RPG increases my learning efficiency.	3.80	.632
Pu4	Learning through CT_RPG increases my computational thinking abilities.	3.70	.483
Pu5	Learning through CT_RPG makes me feel confidence in the learning outcomes.	3.60	.699
Pu6R	Learning through CT_RPG does not help improve computational thinking.	3.60	.843
Mean		3.68	

The analysis results for perceived enjoyment are shown in Table 5. Items Pf5R and Pf6R were reverse-coded items. The mean of perceived enjoyment was 3.75 points. The mean of Pf2 reached 4.1 points.

Table 5. Perceived Enjoyment

Number	Item content	*M*	*SD*
Pf1	Learning through CT_RPG is interesting.	3.80	.789
Pf2	Learning through CT_RPG is novel.	4.10	.738
Pf3	Learning through CT_RPG gives me a new experience in computational logic.	3.90	.738
Pf4	I attain a sense of enjoyment in the learning process with CT_RPG.	3.90	.876
Pf5R	The course of learning through CT_RPG is boring.	3.50	.971
Pf6R	The CT_RPG fails to add fun to the course.	3.30	1.059
Mean		3.75	

The results of the analysis of students' intention to use CT_RPG for learning are shown in Table 6. Item Bi5R was a reverse-coded item. The overall mean of the dimension was 3.68 points. Items Bi2 and Bi6 had greater mean scores of 3.8 points.

Table 4. Intention to Use RPG-Based Learning

Number	Item content	*M*	*SD*
Bi1	I am willing to use a CT_PRG-based learning method.	3.70	.823
Bi2	Learning through CT_PRG can increase my learning interest.	3.80	.632
Bi3	I often use game-based learning methods.	3.70	.675
Bi4	I recommend digital game-based learning methods.	3.70	.675
Bi5R	I think using digital game-based learning methods is unnecessary.	3.40	.843
Bi6	I have a positive rating for using CT_PRG for learning.	3.80	.789
Mean		3.68	

Table 7 shows that the overall mean for effectiveness of use was 3.50 points, indicating that the participants held positive attitudes toward the effectiveness of using CT_RPG.

Table 5. Effectiveness of Use

Number	Item content	*M*	*SD*
As1	Learning through CT_PRG helps me understand the course.	3.30	.823
As2	Learning through CT_PRG in the course is useful.	3.50	.707
As3	Learning through CT_PRG improves my computational thinking abilities.	3.50	.527
As4	Learning through CT_PRG increases my acceptance of the course.	3.70	.675
As5	Learning through CT_PRG conforms to my learning goal.	3.50	.707
Mean		3.5	

4.4. Regression Analysis

This study adopted linear regression analysis to explore the relationship between the dimensions in the research framework. The dependent variables were CT_RPG, perceived ease of use, perceived usefulness, perceived enjoyment, and intention to use RPG-based learning. The dependent variables and their corresponding independent variables are shown in Table 8. Based on the results in Table 8, the relationships of the regression results are illustrated in Fig. 9; arrows indicate the direction of the effect related to each dimension, and the path coefficients are marked.

Table 6. Table of Regression Analysis

Dependent variable	Independent variable	Non-standardized coefficient B	Non-standardized coefficient Standard error	Standardized coefficient β	T	Significance
CT_RPG	(constant)	1.259	.905		1.391	.202
	Perceived ease of use	.678	.249	.694	2.729	.026
	(constant)	.779	.853		.913	.388
	Perceived usefulness	.789	.228	.774	3.459	.009
	(constant)	.924	.439		2.104	.069
	Perceived enjoyment	.707	.110	.915	6.411	.000
Perceived ease of use	(constant)	1.425	.987		1.443	.187
	Intention to use RPG-based learning	.582	.261	.619	2.229	.056
Perceived usefulness	(constant)	.397	.232		1.710	.126
	Intention to use RPG-based learning	.883	.061	.981	14.378	.000
Perceived enjoyment	(constant)	.104	.810		.129	.901
	Intention to use RPG-based learning	1.022	.214	.860	4.773	.001
Intention to use RPG-based learning	(constant)	.749	.645		1.161	.279
	Effectiveness of use	.855	.182	.857	4.696	.002

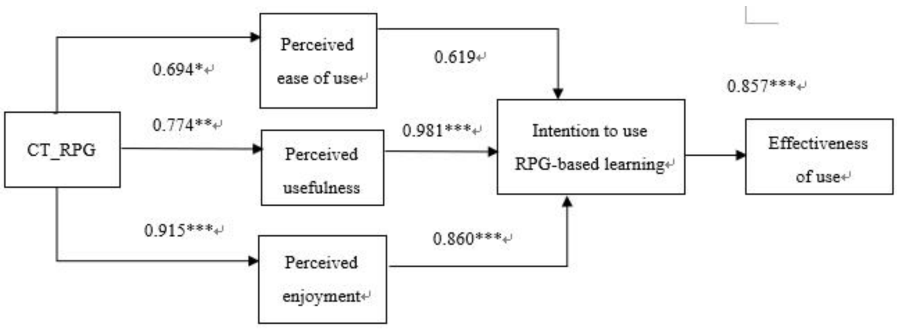


Figure 9. Relationships in Regression Analysis Results

Figure 9 shows that H1, H2, H3, H5, H6, and H7 were significant. The regression analysis result for H4 did not reach the level of significance (p = .056 > .05), indicating that perceived ease of use did not positively affect the intention to use RPG-based learning. Thus, H4 was rejected. The possible cause for such rejection may be the complicated operation of the game, which did not provide convenient use to the students. Thus, perceived ease of use had no significant effect on the students' intention to use RPG-based learning.

5. Conclusions and Recommendations

The questionnaire responses revealed that the item that scored lowest in the dimension of effectiveness of use was As1 "Learning through CT_PRG helps me understand the course," with a score of only 3.3

points. Observation results indicated that the students could not gain a further understanding of the course by operating the game-based teaching materials. A possible reason might be that the present study lacked a detailed teaching plan for the course, and the teaching activity was not implemented in an official course. The students had no preliminary knowledge of the subject. Thus, the game operations and materials did not facilitate the students' understanding of the course. The mean score of the perceived enjoyment dimension was 3.75 points, which represented the highest score among all mean scores of the dimensions. The result suggests that enjoyment was a major positive aspect of the game-based learning for the participants; however, the effect size was limited. If future game-based teaching materials can strengthen enjoyment and interactions, such features may further attract users. In the perceived enjoyment dimension, Item Pf2 "Learning through CT_RPG is novel" scored 4.1 points, marking the highest score. This might be because the participants had not played similar learning-oriented games. Accordingly, they perceived the game to be a novel learning method when playing it for the first time. In addition, the application of an RPG in education is rare. The result indicates that game-based learning has considerable room for development.

The questionnaire statistical results demonstrated that CT_RPG-based learning positively affected perceived ease of use, usefulness, and enjoyment, implying that the developed CT_RPG exerts positive effects on the participating students' perceived ease of use, usefulness, and enjoyment regarding the effectiveness of computational thinking education based on CT_RPG. Thus, we recommend that the design of various teaching materials should consider students' satisfaction in the three dimensions to ensure positive effects on their intention to use and effectiveness of use.

Perceived usefulness and enjoyment positively affected the students' intention to use RPG-based learning. Most of the students opined that game-based teaching materials should be designed following principles that promote usefulness and enjoyment to increase students' intention to use RPG-based learning. Thus, game-based learning materials may be used in subjects that students generally lack interest in to excite their learning motivation in the subjects. If a game is designed without considering the aspect of usefulness or enjoyment, students' intention to learn through the game may decrease. Following the increase in their intention to use RPG-based learning, the participants perceived improvement in their effectiveness in course learning, which increased their acceptance of the course. Therefore, game-based learning is suitable for increasing students' acceptance of subjects that are difficult to learn. Game-based learning materials can also increase students' confidence, which in turn improve their intention to learn as well as their learning effectiveness.

The quantitative analysis of learning effectiveness revealed that the students' scores differed significantly before and after the game-based learning. However, the students did not have experience in learning programming. They were unfamiliar with the subject and showed little progress in their performance. Thus, we suggest that game-based learning materials may help improve students' learning effectiveness; however, such materials do not apply to students who are learning from the beginning. In other words, game-based learning is suitable for students with prior knowledge. In this scenario, the students' performance progress may be demonstrated, and their knowledge of the subject may be deepened. However, this assumption requires confirmation in future studies. The development of items should be assisted by employing specialized instructors to aid students without prior knowledge in understanding relevant concepts and answering questions. For teaching activities in a course, we recommend using game-based learning as a supplementary element to traditional teaching to strengthen the effect of game-based learning.

The small sample size of this study means that the results cannot be generalized to students of different ages and majors. We recommend future scholars extend their research scope to elementary, junior high, and senior high schools and divide the participants by departments or divisions to facilitate analysis of variations attributable to student demographics. This enables a further understanding of how students of different backgrounds and age groups perceive game-based learning differently. Furthermore, the difficulty level of game-based learning materials can be adjusted meet the needs of specific age groups. The aim would be to analyze and determine the age groups most suitable for game-based learning so that participants for future game-based learning can be identified.

Because the present study was conducted during the pandemic period, most schools adopted distant education. Students could not receive immediate assistance in answering items and operating the game. Thus, we note that personnel assistance is required for learners who operate game-based learning for the first time to avoid participants from quitting.

This study employed an RPG as the design platform because the modular design facilitated rapid composition of the game-based learning material. However, the gaming model was relatively limited. If future researchers have the ability to create games on other platforms, different gaming mechanisms can be utilized to design teaching materials. In addition, mobile applications designed to be operated on mobile devices can be developed for game-based learning, which may increase the convenience and popularity of the game. Moreover, the original digital game concepts can be modified into physical board games for learners to play in the classroom. Learning based on physical games can also be a direction of future experiments.

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