

# Using a Level-based RPG Educational Game to Enhance Students' Knowledge of Mathematics

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**Abstract**— This study utilized RPG Maker MZ to develop a simulated mathematical educational game that enables learners to immerse in the digital game while also acquiring knowledge about all units in Mathematics 3A, such as radian measure, trigonometric function graphs, trigonometric angle sum and difference identities, superposition of sine and cosine functions, exponential function, logarithms and its laws, logarithmic function, and plane vector operations, inner products, and applications. The said mathematical educational game aims to increase students' learning interests and assist them in achieving better learning efficiency. Ninety-three second-graders from a vocational senior high school participated in the study and were given questionnaires to fill out afterward. This study discovered that mathematical educational games enable students to not only go through a variety of situations and experiences but also improve their learning efficiency and their ability to think about the problems around them through virtual life situation-based games. This type of interaction can assist students in better understanding and mastering the flexible application of mathematical concepts and knowledge in a variety of life situations.

**Index Terms**—mathematics, RPG, e-learning, digital game-based learning.

## I. INTRODUCTION

With the rapid advancement of digital teaching, many schools and businesses have begun to use it as a supplement to the traditional teaching model. By combining the characteristics and advantages of digital games with educational theory and subject knowledge, digital game-based learning creates an environment that can promote learners' learning efficiency [1].

During the learning process, learners become interested and actively engaged in learning as a result of digital games' multimedia elements, interesting design, and interactivity [2]-[3].

Digital game-based learning provides learners an experience that differs from traditional teaching [4]. Furthermore, digital games also provide timely feedback and reward mechanisms that offer learners timely positive reinforcement, increasing their learning motivation and satisfaction.

## II. RESEARCH MOTIVATION AND PURPOSE

"Digital educational games" is a teaching tool that combines education and game elements to improve learners' interest in subject knowledge and learning effectiveness. In this rapid digital technology development era, digital educational games have become a hot research topic. Many educators and scholars have begun paying attention to this field, attempting to combine education and games. When it comes to subjects that educational game users are unfamiliar with and fearful of, the games can quickly touch their hearts and help them accept the subjects more quickly.

Hsu [5] discovered that game elements could stimulate students' interest and motivation to learn, make learning easier and more enjoyable, and improve learning efficiency. A game-based learning environment, for example, can increase student engagement and enthusiasm, making it easier for them to memorize and understand subject knowledge.

Digital educational games can also be personalized based on students' learning styles and academic levels to provide learning experiences that meet their needs. Such personalization feature of digital educational games helps ensure that students' learning needs can be better met while also improving their learning efficiency and

sense of accomplishment. Digital game-based learning, as a teaching method, has transformed conventional teaching environments and methods by allowing teachers to use a variety of situation-based game software to create virtual learning environments full of fun and challenges. Besides, a digital game-based learning system can also be used to assess students' learning effectiveness.

Role-playing games (RPGs), 3D animation teaching materials, and educational game applications are rarely used for teaching and learning in today's schools. As a result, this study developed a level-based educational game for Mathematics 3A and aimed to promote enrichment in students' desire through a novel learning method, allowing learners to learn with interest and achieve greater learning efficiency.

Core competency encompasses all information, ability, and attitude that a person should possess to be prepared for daily life and future challenges. The core competency concept emphasizes that learning should be wider than the knowledge and skills taught in school. Rather, learning should consider real-life scenarios and promote holistic development through action and self-development [6], [7].

This study aims to design and develop a virtual life situation-based mathematical RPG that allows learners to integrate into the game and self-check their learning effectiveness while playing. The said mathematical RPG covered all units in Mathematics 3A, such as radian measure, trigonometric function graphs, trigonometric angle sum and difference identities, superposition of sine and cosine functions, exponential function, logarithms and its laws, logarithmic function, and plane vector operations, inner products, and applications.

### III. LITERATURE REVIEW

#### A. Math A

Mathematics is a practical science of patterns. In teaching, the importance of mathematics should be emphasized in interdisciplinary integration [8]. In the curriculum guidelines for the 12-year basic education, vocational senior high school, and the domain of mathematics (Grade 10 to Grade 12), mathematics is regarded as a tool for life application and a process developed by a series of life experiences and continuous renewal of learning [9].

Learners can understand basic mathematics concepts after going through the learning process of awareness, knowledge, and practice. Students move from numbers, quantities, shapes, arithmetic, symbol algebra, number and shape transformation, and abstract mathematics to internalize mathematical concepts and problem-solving strategies. Through this process, they can appreciate the art of mathematics in simplifying complexity, understand mathematical structures, and allow it to influence their reasoning ability. Students' ability to observe, calculate, solve problems, infer, communicate with mathematical symbols, and cultivate mathematical application and modeling capabilities can be developed to solve everyday problems, explain natural phenomena, and analyze social issues appropriately and quantitatively.

Students with high mathematics needs are advised to take Math A and then Math I, an enrichment and expanded elective course determined by the Ministry of Education. Meanwhile, students with varying mathematics needs can take Math A and Math I or Math II. Students with low mathematics needs can take Math B only or Math II after Math B. Given the difficulty of orienting senior high school students too early, the mathematics curriculum guidelines should be designed to make the transition as easy as possible so that students who study Math B in Grade 11 have the opportunity to learn further the prerequisite knowledge required for Math II and select the Math II elective [10]. Math A was used in this study to develop a level-based mathematical RPG system.

#### B. Digital Game-Based Learning

Traditional learning methods are typically teacher-centered, emphasizing knowledge instillation and students' passive acceptance [11], [12]. These methods can easily cause students to lose motivation to learn, become bored with the learning content, and thus lose their overall learning interest. In most cases, students will study only to prepare for exams rather than to understand and master the material truly.

Game-based learning, on the other hand, emphasizes using games to aid with teaching and improve students' learning motivation and learning interest. Through the essence and characteristics of games, students can absorb knowledge and skills more easily. Additionally, game-based learning can also stimulate learners' intrinsic motivation, allowing them to participate more actively in the learning process and improve their learning

effectiveness. Therefore, game-based learning has emerged as a critical teaching method in education today [13]-[16].

This type of learning model is both entertaining and educational. Through this teaching method, learners can have a fun and enjoyable way of learning. Furthermore, digital game-based learning can assist learners in developing their cooperation, problem-solving, and higher-order skills [17]-[20].

To summarize, learners can not only learn in an interesting and challenging environment with digital game-based learning but also harvest more learning outcomes and a sense of accomplishment.

### *C. Digital Educational Games*

With the continuous development of science and technology, e-learning has become an important learning and teaching model in modern education, with widespread application to higher education, vocational training, and all education levels in both elementary and secondary schools [21], [22].

E-learning is not only a modernization of the traditional teaching model but also an entirely new way of education. E-learning typically employs a variety of electronic devices and software to provide learning resources and learning experiences, such as online courses, e-books, video courses, virtual classes, and game-based learning. These learning resources and experiences help students learn more autonomously, improving learning efficiency and effectiveness. E-learning also provides a more flexible way of learning by allowing students to study anytime and anywhere as they are no longer limited by time and space. This is particularly important for students who require flexible learning [23]. Furthermore, digital games improve students' speed and concentration when performing mathematical calculations [24].

Game-based learning is suitable for learners of all ages and in a variety of fields. Students can integrate learning into entertainment and have fun by playing games. Game-based learning pace and difficulty can also be individually adjusted to meet students' needs and learning styles. Since the visual and audio effects of game-based learning are often more vivid and enchanting than traditional teaching methods, game-based learning can attract students' attention and interest. Furthermore, game-based learning is typically interactive and exploratory, allowing students to use games to analyze and solve problems [16], [25].

E-learning encompasses not only online and blended learning, but any teaching practice in which digital tools and technologies are used to improve students' learning experiences and educational outcomes [26], [27].

### *D. Six Key Factors of Digital Game-Based Learning*

According to Yang [4] and Wang [28], a game should have six key factors: rules, goals, feedback on outcomes, competition/challenge, interaction, and story. These six key factors are the foundation for digital game-based learning's success in attracting learners, and they are described in detail below:

#### *1) Rules*

A game's rules are critical to success. The rules of a game must be clear so that learners can understand the game's purpose, process, method, rewards, and other elements and can play the game fairly. By following the rules of a game, learners can develop self-discipline and learn how to make the best decisions under pressure, improving their self-management and problem-solving skills.

#### *2) Goals*

Setting interesting and challenging game tasks can encourage learners to participate more actively in learning by stimulating their curiosity and exploration spirit, convincing them to spend more time and energy thinking about and solving problems.

#### *3) Feedback on outcomes*

Feedback on outcomes is critical to learners' learning effectiveness and motivation. Through timely feedback on outcomes, learners can confirm their learning progress and effectiveness and receive positive incentives to continue learning. In a game, incentives can be rewards, achievements, rankings, titles, or other items that can increase students' learning motivation and enthusiasm, making learning more challenging and interesting.

#### *4) Competition/challenge*

The competition and challenge in digital games can provide learners a completely new learning environment, allowing them to develop various abilities. Competition can encourage learners to strive and excel in a challenging environment. Learners can improve their ability to use their knowledge and skills more effectively to complete

required tasks with limited time and resources. In addition, challenge can help learners learn to deal with pressures and difficulties while strengthening their resilience and confidence. Learners can also learn how to work collaboratively with others to solve problems and achieve common goals. These skills are extremely valuable in real life as they can help the learners better adapt to future learning and working environments. However, challenges that are too difficult can also have a negative impact on the learners. Therefore, the design content of the digital game was discussed three times with mathematics teachers of vocational senior high school, and adjustments were made accordingly during the design process of this study.

#### 5) Interaction

Yang [4] and Wang [28] stated:

(a) A game can interact with players through goal-setting, rewards, and achievements and stimulate players' learning motivation and behavior.

(b) It can be either cooperative or competitive. Cooperation can promote teamwork and collaboration skills, while competition can improve competition sense and skills.

(c) Digital games can create a variety of virtual environments in which players can go through different situations and experiences. This interaction can help players better understand and master different concepts and knowledge.

#### 6) Story

According to Prensky [13] and Yeh and Yang [29], a story can create a situational learning environment, making it easier for learners to understand and master the learning content and improve learning efficiency. A story can also help learners enter and participate better in the games, improving their engagement and initiative. To improve learning motivation and learning effectiveness, digital game-based learning combines the entertaining nature of computer games with the learning nature of teaching content.

The flow theory suggests that if learners can enter a flow state while playing digital educational games, they will be more focused and more likely to absorb and understand the learning content [29], [30]. Interesting elements can boost learners' learning motivation and improve their interest and engagement in the learning content [31], [32].

### IV. RESEARCH METHOD AND DESIGN

#### A. Steps to System Making

To develop the system used in this study, the researchers used STEAM-RPG Maker MZ.

The following Math A teaching materials were used as references [33], [34]:

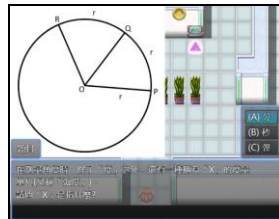
Following the discussions with mathematics teachers about the system developed in this study, the researchers determined that the display of learning in terms of cognition, affection (including attitude), and life applications should be prioritized. During the development of the system using STEAM-RPG Maker MZ, knowledge from all units in Mathematics 3A was integrated, life situations were created, and mathematical questions were incorporated into the game world before real-world situations and learning content were chosen to design test questions at various levels, steps, or stages. The Mathematics 3A units that were used are as follows: radian measure, trigonometric function graphs, trigonometric angle sum and difference identities, superposition of sine and cosine functions, exponential function, logarithms and its laws, the logarithmic function, and plane vector operations, inner products, and applications.

This study aims to determine whether the game elements will stimulate students' interest and motivation in learning, help display their ability to solve daily life problems using mathematics and help improve learning efficiency.

The Math A RPG system developed in this study follows a creative story plot. The 3A system elf informs the protagonist Hsiao-Jih that she can only leave this world if she completes the tasks he assigned. After Hsiao-Jih wakes up early in the morning, her mother invites her to participate in a museum event before returning home to finish her homework. Hsiao-Jih goes to the swimming pool in the afternoon for a usual swim. A friend at the swimming pool approaches Hsiao-Jih and asks for help. After assisting her friend, Hsiao-Jih discovers that a competition will be hosted by the swimming department, so she goes to the beach to watch the competition. After the competition, the 3A system elf directs her to the temple to have her ending judged.

Fig. 1 depicts a designed question and possible answers to choose from. Fig. 2 shows that if the correct answer is

chosen, NTD 2 is awarded. Fig. 3 shows that the correct answer will be revealed if the answer is wrong. Fig. 4 shows that regardless of whether the answer is correct or wrong, an explanation will be provided. Fig. 5 depicts the introduction to the story. Fig. 6 shows a life situation-based dialogue. Fig. 7 shows an archaeological question. Fig. 8 shows a life situation-based dialogue. Fig. 9 depicts a non-player character (NPC) guiding the player. Fig. 10 shows another life situation-based dialogue.



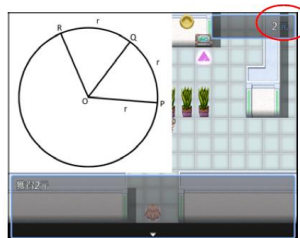
**Question:**

For angle measurement, in addition to “degree,” there is another unit of measurement called “X.”

What does “X” refer to?

- (A) Minute (B) Second (C) Radian

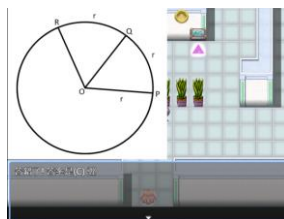
**Fig. 1.** A designed question and answers to choose from



**NTD 2:**

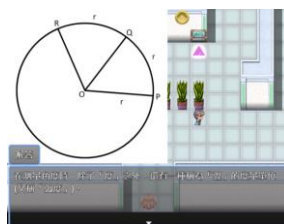
NTD 2 granted

**Fig. 2.** If the correct answer is selected, NTD 2 will be granted



Wrong answer! The answer is (C) Radian.

**Fig. 3.** If the answer is wrong, the correct answer will be revealed



**Explanation:**

For angle measurement, in addition to “degree,” there is another unit of measurement called “radian.”

**Fig. 4.** An explanation will be given regardless of whether the answer is correct or wrong



### 3A System:

Welcome to the Mathematics 3A world. This world includes trigonometric functions, exponential and logarithmic functions, and plane vectors. Only by passing 60 can you escape this world. By the way, I'll tell you a secret. There's a little secret hidden in every scene.

**Fig. 5.** Introduction to the story



### Mother:

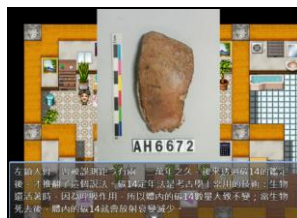
Hsiao-Jih! Are you up?

There's an event in the museum this morning. Do you wanna go?

But you haven't finished your homework yet, have you?

Don't forget to come home and do your homework after visiting the museum.

**Fig. 6** A life situation-based dialogue



The age of this human skull fragment discovered in Zuojhen District had been mistakenly estimated to be 20,000 to 30,000 years. This statement was not overturned until after carbon-14 dating. Carbon-14 dating is a commonly used technique in archaeology. When an organism is alive, the amount of carbon-14 in the body is roughly unchanged due to respiration; when the organism dies, the amount of carbon-14 in the body begins to decrease as the carbon-14 undergoes radioactive decay.

**Fig. 7.** An Archaeological Question



### Hsiao-Jih:

Finally done!

Eek! The rain has stopped!



That's great!

I might as well go for a swim at the swimming pool!

**Fig. 8.** A life situation-based dialogue



**Swimming Pool Attendant:**

Welcome!

We're holding a swimming competition on the beach today. You're welcome to watch the competition!

**Fig. 9.** An NPC gives guidance to the player



**Friend Known from the Swimming Pool:**

Here you are, Hsiao-Jih! The competition is heating up!

**Fig. 10.** A life situation-based dialogue

#### B. Teaching Experiment

The experiment was conducted in a national vocational senior high school. There were 93 second-graders in total. Table I shows the results of the questionnaire survey analysis.

**Table I.** Questionnaire survey analysis

Sum - Percentage	Column labels					
Question	Strongly disagreed	Disagree	Fair	Agree	Strongly agree	Total
After passing the RPG levels, I have acquired considerable knowledge of using mathematical formulas.	1%	2%	37%	38%	21%	100%
After passing the RPG levels, I have acquired considerable knowledge of the explanatory power of mathematics.	1%	2%	41%	35%	22%	100%
After passing the level-based RPG learning test, I have acquired considerable knowledge of solving mathematical problems.	2%	1%	38%	39%	21%	100%
After the level-based game, I have full confidence in my understanding of this course.	2%	4%	34%	40%	20%	100%
What I have learned in the level-based RPG is helpful in life.	1%	0%	29%	43%	27%	100%
The use of level-based game teaching materials can make learning more efficient.	1%	0%	30%	39%	31%	100%
The level-based game teaching materials can make me think about problems around me.	1%	1%	39%	39%	21%	100%
The game will be helpful in my future workplace.	0%	1%	35%	45%	19%	100%
The level-based game process makes it easier for me to absorb relevant knowledge in the classroom.	1%	1%	33%	42%	23%	100%
The level-based game has stimulated my curiosity.	1%	1%	24%	43%	32%	100%
<b>Total</b>	<b>1%</b>	<b>1%</b>	<b>34%</b>	<b>40%</b>	<b>24%</b>	<b>100%</b>

The experiment in this study was performed in a vocational senior high school. School teachers, parents, and

students' permission was obtained in advance. The following conclusions are drawn from the questionnaire survey analysis:

- 1) After passing the RPG levels, most of the respondents' knowledge of using mathematical formulas improved to a certain extent. The total proportion of "Agree" and "Strongly Agree" was 59%.
- 2) In terms of the knowledge of the explanatory power of mathematics, the respondents' views were mixed. "Fair" and "agree" accounted for similar proportions, while the proportion of "strongly agree" was as low as 22%.
- 3) Similar to the first point, the respondents' ability to solve mathematical problems improved. The total proportion of "agree" and "strongly agree" was as high as 60%.
- 4) After the game, most respondents' understanding of the course improved to a certain extent. The total proportion of "agree" and "strongly agree" was as high as 60%.
- 5) More than 70% of the respondents felt that what they had learned in the level-based RPG was useful in life.
- 6) Most respondents believed that using level-based game teaching materials could make learning more efficient. The total proportion of "agree" and "strongly agree" was as high as 70%.
- 7) Approximately 80% of the respondents believed that level-based game teaching materials could make them think about problems around them.
- 8) More than 60% of the respondents thought the game would be useful in their future workplace.
- 9) Generally, the respondents were optimistic about the level-based game's effect on improving the absorption of relevant knowledge in the classroom. The total proportion of "agree" and "strongly agree" was as high as 65%.
- 10) More than 70% of the respondents stated that the level-based game stimulated their curiosity.

As part of the interaction between students and the level-based RPG, a reward mechanism was established to encourage students to obtain achievement goals with high reward points, thereby stimulating their learning motivation and behavior. Competition in the game improved students' competition sense and skills in the same virtual classroom environment. The virtual life situation-based game promoted the interaction between the players (students) and the living environments in the game, allowing the players (students) to go through a variety of situations and experiences. This type of interaction can assist the players (students) in better understanding and mastering the flexible use of mathematical concepts and knowledge in various life situations.

## V. CONCLUSION AND RECOMMENDATION

### A. A. Conclusion

The researchers anticipated that the Math A RPG system developed in this study would foster interaction between students' professional knowledge about society, cultivate students' experiences in participating in social situations, and enrich students' communication skills in mathematics for them so that they can use these skills in the future. This is the study's focus and expectation. The researchers also aimed that the course would be made richer and more interesting, that the essence of mathematical knowledge would be presented in a lively manner, and that students would learn about the flexible use of mathematics (miscellaneous) in all social classes.

Generally, there is support for using level-based RPGs as teaching materials. The analysis results suggest that such teaching materials help improve students' abilities to a certain extent while enhancing their learning efficiency and stimulating their learning motivation.

Using level-based RPGs as teaching materials can help students learn assistance in a variety of ways, such as improving mathematical their intelligence, enhancing their problem-solving skills, strengthening their understanding of the course, and stimulating their curiosity, thinking, and learning interest. Moreover, level-based RPGs can make learning more efficient by helping students improve their ability to understand and apply mathematical knowledge. Life situation-based learning can also simulate the experience for future social and professional life.

In the ever-changing environment of modern society and under the influence of a wide range of technological and digital media, the Math A RPG system developed in this study can encourage students to play a digital mathematical game and discover mathematical implications and corresponding curriculum guidelines, thereby stimulating their curiosity and exploration impulse at the bottom of their hearts and preparing them to become flexible users of mathematics in the future.



### B. B. Recommendation

Based on the findings of this study, the researchers developed the following recommendations:

- (1) For more efficient comparative analysis, the teaching verification should be expanded to ten vocational senior high schools. Specifically, the use of educational games in each school should be observed and compared.
- (2) A cross-national comparative analysis should be performed.

### VI. ACKNOWLEDGMENT

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