Mystery Rooms: Puzzle Game for Learning Mathematic Arithmetic

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Abstract— **Mathematics is one of the most important knowledge areas for everyone because it is commonly used in our daily life and even in professional areas such as science, engineering, and economics. The importance of mathematics cannot be denied even for children. For example, children need to recognize the amount of money, so they are not confused when buying something. They also need mathematics to know about the time. Mathematics is everywhere. Mathematics is so important, but the learning process may be difficult for children. To encourage children to learn about the mathematics concept, a game application that can teach them simple mathematics knowledge while having fun is proposed for this project. The main game engine to be used during the development of this application will be Unity. The Waterfall model will be the methodology used which involves the analysis, design, implementation, and testing phase. This project aims to teach simple mathematics arithmetic to primary school student while they can have fun. After developing and evaluate the game, there are some improvements that can be done and most participants which test the game are satisfy with the project output.**

Keywords- mathematics; arithmetic; learning process; game

I. INTRODUCTION

The nature of mathematics has been discussed over the last few decades as there are so many writings written such as the article written by John A. Dossey. Dossey discussed that the concept of mathematics may influence the view of society towards mathematics [4]. From this, the teaching method of mathematics and communicate subtle messages to children about the nature of mathematics that "affect the way they grow to view mathematics and its role in their world" [4]. It is undeniable that mathematics is important, and the educators need to focus on the nature of mathematics in the development of curriculum, research, teacher training and assessment as they are trying to understand its impact on the teaching and learning of mathematics [4].

Mathematics is important in two ways, which serves as a gatekeeper for all the opportunities in employment and study. Mathematics also contains the important knowledge and skills for participating in society as an adult. Mathematics is an important element for young people to live a better life. Hence, mathematics learning in primary schools is very important because it is the foundation for all the later mathematics learning which comes in two ways. First is because primary school teaches students about the concepts of early mathematics which are the roots for later mathematical ideas. Second will be the primary school mathematics learning experiences will become the young people's belief in their ability in doing mathematics and this build their willingness to engage with mathematics [17].

As technology rapidly grown, technology became an important tool in education. Technology had provided the students with accelerated learning, easy-to-access information and it is also an opportunity for them to practice the knowledge they learned. Video games as one of the products from the technology is an interactive digital entertainment which can be played using game console, computer, tablet or mobile phone. It is an electronic game in which the player will control the images on a video screen using a specialized electronic gaming device such as computer and mobile device. When the player clicks, presses or types something, the game will respond according to the rules set up by the game creator. Video games are a different way which provides fun and expresses creativity compared to the traditional games.

The learning process of mathematics may be difficult for students when they lack understanding about the basic concept of mathematics. This can be overcome by having an interesting and fun time. Students are shaping, living and immersed within a modular, meme-soaked, multimedia world and video games are a dominant art form within that world. An application which teaches the basic arithmetic of mathematics should be develop like the proposed game application which mainly to teach the basic mathematics to the children especially for primary school student as this may improve their interest and knowledge towards mathematics in an interesting and fun way.

The gameplay for the proposed game should be simple as this is designed for primary school students. Puzzle based element will be implemented for the mathematics operation which require the user to move the number and symbols such as +, -, = to the correct location to calculated to the correct

answer. The user will also require doing some simple counting to solve the quiz in the game. This may improve the knowledge towards mathematics which may be helpful during our daily lives which involve many mathematics calculations such as counting the money.

II. PROBLEM BACKGROUND

Mathematics learning during primary school is important for students as mathematics is the foundation of later mathematics learning, but it is possible for students to face problems during the learning process. Lack of interest in mathematics subject and practice in solving mathematic problems is one of the reasons students struggle with mathematics. Besides, the learning process only from textbook will make the student feel very bored for the mathematics subject. Inability of mathematics knowledge from elementary level will cause serious effect to the students as mathematics is the main key for opportunities in further study and employment. For example, they may be unable to recognize the money when they are buying something even though they already learned about the value for each money in school.

Mathematics curriculum is important in primary grades as they can help the students to understand and acquire the basic mathematical concepts and computational skills. The failure to understand and learn mathematical concepts in the elementary level may affect children's interest in the mathematics field. This may also affect the ability for them to learn and acquire higher level mathematics skills [19]. Therefore, it is important to develop an application which able to teach the primary school students about the basic of the mathematics including the counting and arithmetic in an interesting way as this may enable them to gain the basic mathematic knowledge and gain their interest in a fun and interesting way.

III. PROJECT AIM

This project aims to develop a puzzle-based game which can teach mathematic arithmetic.

IV. PROJECT OBJECTIVES

The objectives of the project are:
 a) To analyse the requirements of video games in learning basic mathematic arithmetic.
 b) To design and develop basic mathematical operations puzzled-based video game for primary school students (Year 2).
 c) To evaluate the proposed mathematical operations puzzle-based video game for primary school students (Year 2).

V. MATHEMATIC ARITHMETIC

Change in the distribution of strategies or procedures used by children during problem solving is the most thoroughly studied developmental and schooling-based improvement in arithmetical competency [2]. Children typically count both

addends such as (5+3) in the early learning of how to solve the simple addition problems. Counting procedures normally will be executed using the aid of fingers (finger counting strategy) for children and sometimes without them [8]. Typically, the counting procedure involves stating the larger valued addend and then counting the number equal to the value of the smaller addend such as counting 4, 5, and 6 to solve 3 + 4.

Arithmetic operations consist of four basic operations, which are add, subtract, multiply and divide two or more values which is the basic operations that will be applied in this proposed game. Addition is the basic mathematical skill which adding two or more numbers together denoted by the symbol '+'. For example, 3+5=8. Subtraction shows the difference between two numbers, which are used to calculate what is left when things are taken aways from other words denoted by the symbol '-'. For example, 10-2=8. Multiplication is also known as the repeated addition denoted by the symbol 'x' which helps us to find out the total when a number is repeating several times. For example, 3x4=12. Division is a skill which divide thing into equal part, or several parts denoted by the symbol '÷'. For example, 4÷2=2.

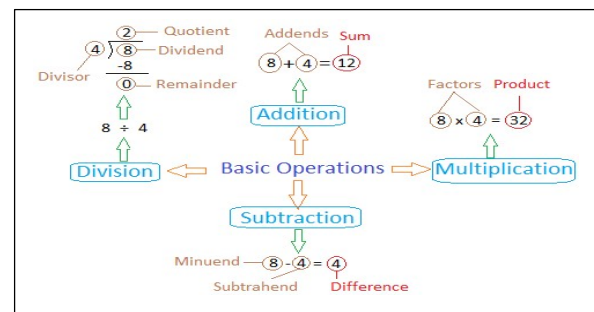Figure 1.   Arithmetic operations (https://www.basic-mathematics.com/basic-operations.html)

VI. SLIDING PUZZLE

Sliding puzzle first introduced in 1880. After it has been introduced, people all around the world were engrossed to try solving the sliding puzzle which known as the 15 Puzzle. This puzzle is made of 4-by-4 grid, which there is 15 numbered squares and left one space empty. The main idea in order to solve this puzzle is to scramble the numbers and rearrange them in order by sliding each number accordingly [21].

Noyes Chapman which is an upstate New York postmaster had come up with the idea of sliding puzzle during 1870s and invented the first sliding puzzle during that time. A commercial version had been introduced by Boston woodworker Matthias J. Rice which was called Gem Puzzle while there exist other versions which sold like Boss Puzzle, the Mystic Square and the Game of Fifteen [21]. Sliding puzzles have the next development in about 1909 by Lewis W. Hardy which invented the first sliding puzzle using rectangular pieces compared to the original one, which is square. The new version had been called Pennant Puzzle which us the baseball theme. In 1927, a new

sliding puzzle which consist of two L-shaped pieces called Ma's Puzzle had been introduced which harden the difficulty of solving the puzzle [21].

The variety of puzzles has increased since the computer started to play a role in designing and solving the puzzles. Hundreds of pictures have been turned into slides and the difficulty of the arrangements of the geometric shapes had been increased to increase the challenging of solvers [21].

VII. GAME ENGINES

Game engine is also known as game framework, game architecture is one type of software development environment which is designed mainly to build up video games, automobile 3D models or architecture models [5]. The game engine can be used by the developers to construct games for consoles, PC, mobile devices and other [5]. There are two famous and widely used game engines, which are Unity and Unreal Engine. The subsection below will show the details of the game engines and choose the most suitable game engine to be used in this proposed game.

VIII. SYSTEM DEVELOPMENT METHODOLOGY

The usage of methodologies for the system development is to taking control of the development process of the system and helps to improving the management. It also helps to simplify, structuring and standardize the development process and specify the techniques to be used in the system. The methodology chosen for this proposed game, Mystery Rooms: Puzzle Game for Learning Mathematic Arithmetic is the Waterfall methodology which is also known as plan-driven development. This methodology is a linear approach where each stage of the workflow must be completed before it can proceed to the next stage. The reason why Waterfall methodology is chosen is because the objectives of this proposal are clearly defined, and it has a fixed budget and timeline. As the project scope of this project is clearly defined, the methodology can work very well to reduce the time and cost [16]. Customer involvement will only be at the beginning. Waterfall methodology consists of five phases, which are requirements, design, implementation, verification, and maintenance [16]. The software development will be done until the verification phases only for this project.
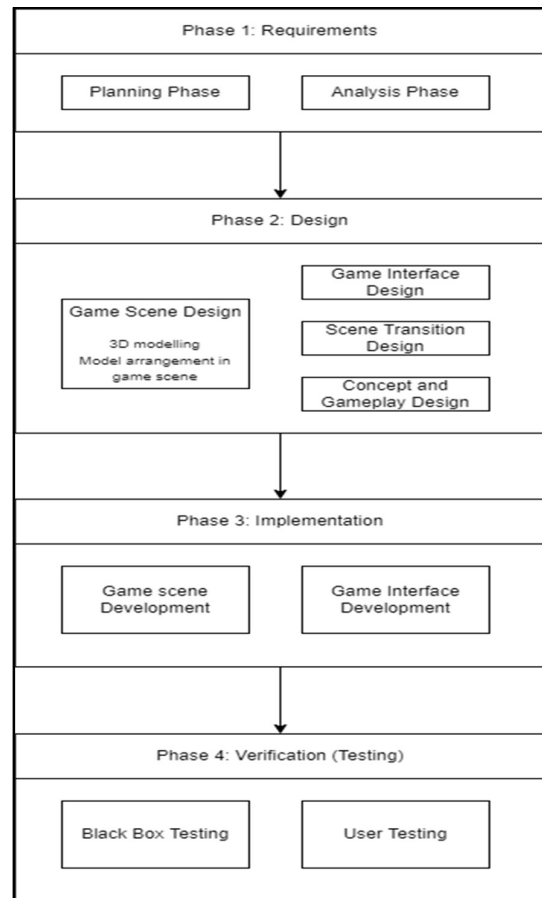

Figure 2.   System framework flow

VI. GAME OVERVIEW

This section will explain the overview of PC game "Mystery Rooms: Puzzle Game for Learning Mathematic Arithmetic" in detail

A. Start Menu.

Fig. 3 shows the home screen interface of the proposed game application which the user can see the logo of the application and they may choose to start or quit the game.

Figure 3.   Start menu

B. Main Menu

Fig. 4 shows the interface after the user clicks the start button on the home scene. Users can click the back button on top left to go back to the home scene or click the house to go to stage selection scene.

Figure 4.   Main menu

C. Stage Selection UI

Fig. 5 shows the stage selection interface which will appear after the user click the house in the main menu scene. Users can choose any stage that has already been unlocked by them to replay.
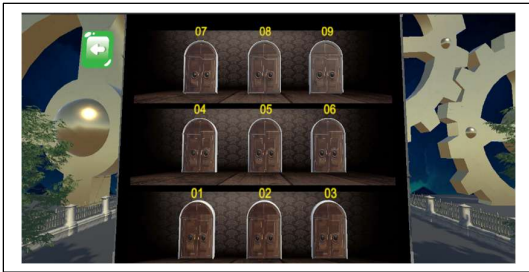

Figure 5.   Stage selection UI

D. Game Scene

Fig. 6 shows the game scene interface which will appear after user chooses the stage they want to play. The general gameplay of the proposed game application is shown in the figure which the user needs to move the puzzle room part to generate path for the character to move towards the door. The arrow in the figure shows the direction that the user may move the puzzle room part by clicking on the button.
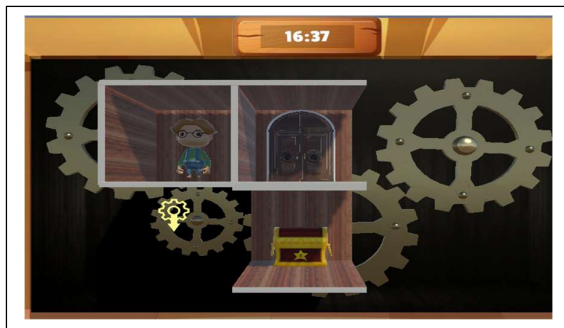

Figure 6.   Game scene

E. Tips UI

Fig. 7 shows the tips interface which will appear after user clicked the treasure box on the game scene. The tips will show an example for the mathematic operation which will be helpful for the user to understand the arithmetic function and help them to solve quizzes to complete this stage
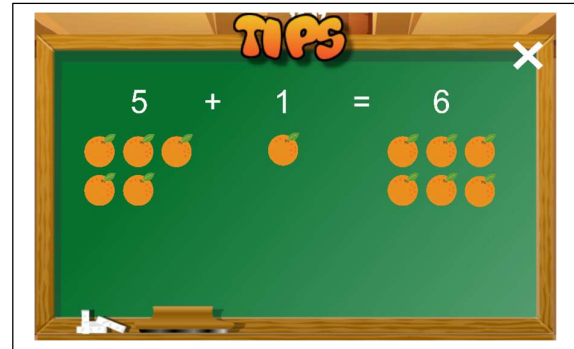

Figure 7.   Tips interface

F. Mathematic Quiz 1

Fig. 8 shows the puzzle element of the proposed game application which mainly on the mathematic arithmetic quiz that the user needs to complete to open the door and then complete the stage. The figure shows one of the arithmetic operations, which is the addition, one type of operation that will be included in the puzzle element. Users need to drag and drop the marble to the container below the total answer shown in the figure to solve the quiz. After user put the correct number of marbles in the container, then they can click the enter button to check for the answer. Each time the user answers wrongly, the three lives on the top right will decrease and game over when three of the life is lost or the timer ends.

Figure 8.   Mathematic arithmetic quiz 1

G. Mathemtic Quiz 2

Fig. 9 shows the second quiz types of mathematical arithmetic. Users need to click any numbers on the top. Then the number will change color to show the difference that it had been selected. Then user need to click the correct answer below to make it a total of numbers equal to the number shown on the right side. After user match all four numbers with the correct answer below, user can click the enter button to check for the answer. Each time the user answers wrongly, the three lives on

the top right will decrease and game over when three of the life is lost or the timer ends.

Figure 9.   Mathematic arithmetic quiz 2

H. Mathematic Quiz 3

Fig. 10 shows the third quiz types of the mathematic arithmetic. Users need to click any numbers below which match the correct answer of the equation. There will be a total of 5 questions for this quiz. Users need to answer all 5 questions to complete the stage. Each time the user answers wrongly, the three lives on the top right will decrease and game over when three of the life is lost or the timer ends.

Figure 10. Mathematic arithmetic quiz 3

I.   Scoring UI

Fig. 11 shows the scoring after the user completed the stage. User may choose to repeat the stage, return to stage selection stage, or go to the next stage by clicking specific button shown in the figure. The scoring will be based on the life left when the user completes the stage.

Figure 11. Scoring interface

X. TESTING AND ANALYSIS

This section explains the usability testing that was carried out to evaluate the developed application. After the user plays this game, a feedback form will be collected from the user. This can help to collect feedback from the user and can be used to improve the game design. This test also tests the completeness of the application functionality and discovers any existing defects.

The questionnaire that will be given to the user is a Google form. There will be a total of 2 questionnaires that will be given to the user, which are pre-test and post-test questionnaire. Pre-tests will be given to the user before they start to play the game to gather some general information about the user. The pre-test questionnaire consists of 6 questions. A summary of the results of this questionnaire will be collected and presented in the form of a pie chart or bar chart. In the end of this testing, there are 26 respondents that had been involved. From the Fig. 12 below, there are 12 respondents are male which take 46.2% in the chart while there are 14 females which take 53.8% of the chart.
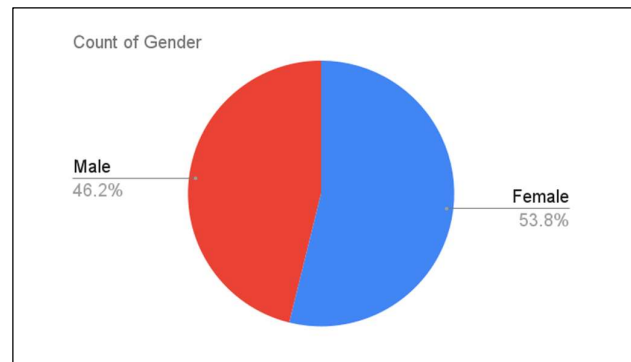

Figure 12. Number of participants based on gender

From Fig. 13 below, most of the respondents agree that the gameplay provides clear instruction based on their experience which are 23 participants, 88.5% from the chart. Besides, 3 participants disagree that the gameplay provides clear instruction based on their experience which are 3 participants, 11.5% from the chart.
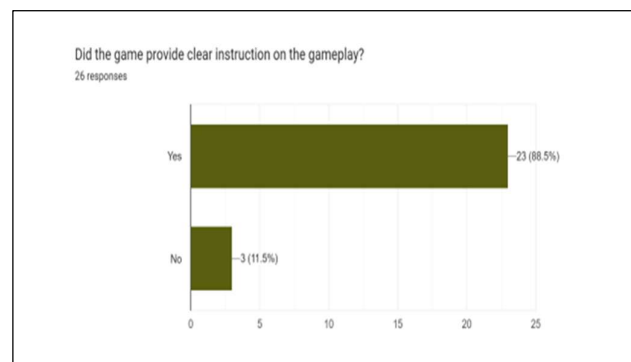

Figure 13. Number of participants regarding game instruction

From Fig. 14 below, most of the respondents are satisfied with the overall gameplay experience, which is 17 participants, 65.4% from the chart rating for scoring of 5 and 4 participants, 30.8% from the chart rating for scoring of 4. Besides, 1 participant, 3.8% from the chart, is not satisfied with the overall gameplay experience.
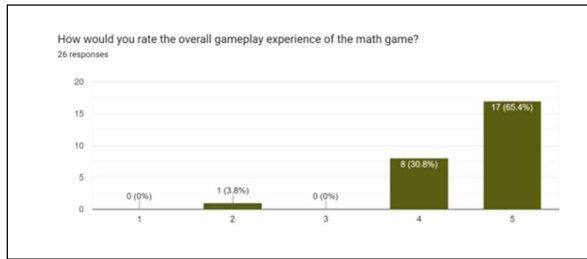

Figure 14. Number of Participants Regarding Game Experience

From Fig. 15 below, most of the respondents agree that math games effectively engage them in learning and practicing math concepts which are 22 participants, 84.6% from the chart while no respondents disagree about this statement. Besides, 4 participants, 15.4% from the chart were not confident about the statement that the math game effectively engages them in learning and practicing math concepts.
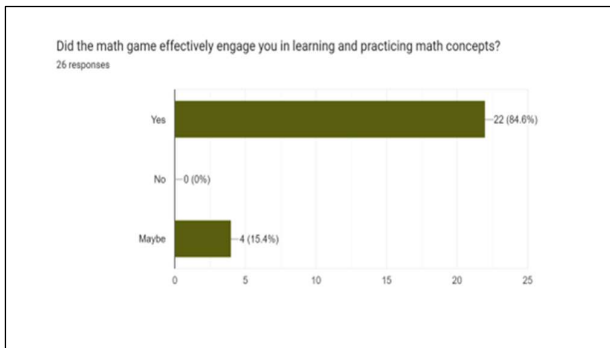

Figure 15. Number of participants regarding game experience

From Fig. 16 below, most of the respondents did feel challenged while playing the game which are 12 participants, 6.2% from the chart while 8 respondents, 30.8% from the chart disagree that the game is challenged. Besides, there is 6 respondents, 23.1% from the chart not sure about the game is challenged.
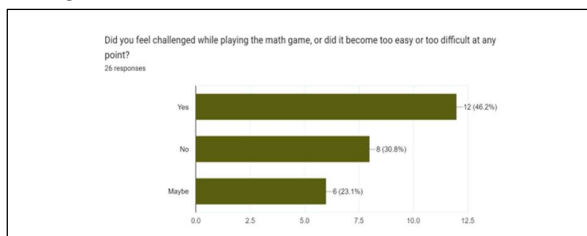

Figure 16. Number of participants regarding challenge level of the game

From Fig.17 below, most of the respondents agree that the scene transition is smooth and precise which are 16 participants, 61.5% from the chart rating for scoring of 5 and 6 respondents, 23.1% from the chart rating for scoring of 4. Besides, there is 3 respondents, 15.4% from the chart rating for scoring of 3 for this statement.
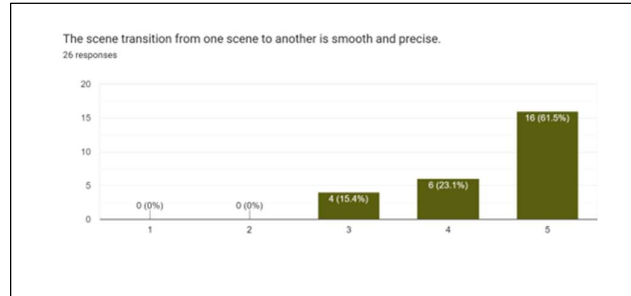

Figure 17. Number of participants regarding smoothness of scene transition

From Fig. 18 below, most of the respondents agree that the interactive buttons are easy to interact with 19 participants, 73.1% from the chart rating for scoring of 5 and 4 respondents, 15.4% from the chart rating for scoring of 4. Besides, there is 1 respondent, 3.8% from the chart rating for scoring of 2 for this statement.
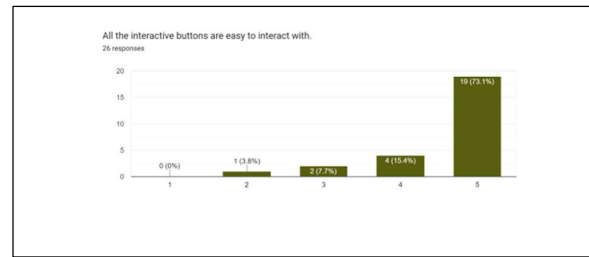

Figure 18. Number of participants regarding interactive buttons

From Fig. 19 below, most of the respondents agree that game provides correct responses after interacting with 17 participants, 65.4% from the chart rating for scoring of 5 and 7 respondents, 26.9% from the chart rating for scoring of 4. Besides, there are 2 respondents, 7.7% from the chart rating for scoring 3 for this statement.
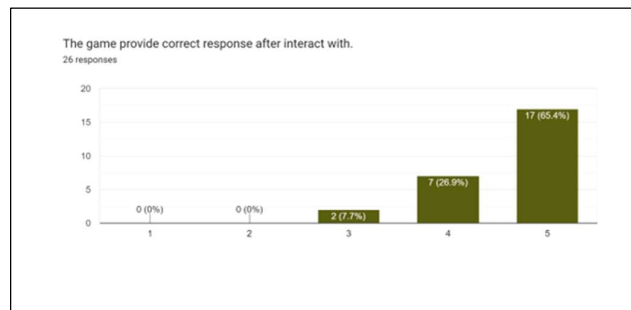
Figure 19. Number of Participants Regarding Correctness of Game Response

XI. CONCLUSION

In conclusion, this paper had discussed the basic concept that will be applied to this project, which are mathematic arithmetic, sliding puzzle. Besides, game engines and system developement methodology that had been used also been discussed. During the development process, there are many problems arise, such as programming logic, UI design, bugs, gameplay design and many others. Fortunately, these problems had been overcome and manage to produce a successful output for this project. In summary, this game is created in 3D objects but with a 2D view, player need to solve the sliding puzzle element at first before they manage to proceed to the mathematical quiz part. The result from the user testing shows most of the testers had enjoyable experience on playing this game.

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