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I. Introduction

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2048. Fig. 1:

Game angry bird (left) [1] and its derivatives (center)[2], (right)[3]

Fig. 2:

Game 2048(left)[4] and its derivatives (center) [5] (right) [6]

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Metamorphosis Edugame using 2048 Game Rules

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Abstract—A game can have many derivatives encompassing diverse topics. One of those games is 2048 game which originally is all about adding numbers. This paper describes how we built a game that introduces its player to metamorphosis process using 2048 game rules on the mobile platform. The experimental results showed that adolescent and adults could play the game well, but not so for children.

Keywords—edugame; metamorphosis; mobile platform; mobile platform

I. INTRODUCTION

In the development of video games, two ways usually were taken: building from scratch or modifying an existing video game. Modification means making changes to components of the original video game, such as assets, gameplay, sound or any other components. Examples of games that were modified from its original version are shown in Fig. 1 and 2. Angry Birds game and its derivatives in Fig. 1 shows that the modification was mainly about the gameplay, while the most of its assets remained. 2048 game and its derivatives in Fig. 2 depicts that the modification was about gameplay and asset, while the game goal remains the same: the number of 2048.

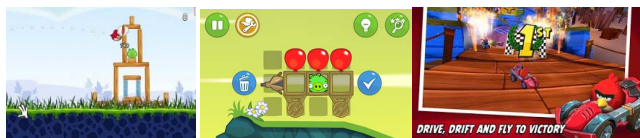


Fig. 1. Game angry bird (left) [1] and its derivatives (center)[2] ,(right)[3]

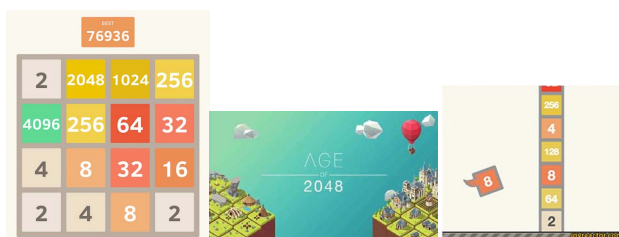


Fig. 2. Game 2048(left)[4] and its derivatives (center) [5] (right) [6]

To construct a derivative game, one can use Game modding tools [2] or create from scratch. Fig. 3 shows examples of game modding tools and game mods of Minecraft game. Game mod or game modding is a modification of the original game using the tools available by the game. This modification can modify the assets or gameplay of the original game.



Fig. 3. Game modding tools[8] and game mods[9]

Game 2048 is the game that will become the focus of this research. The 2048 [10] game is a game created in 2014 by Gabrielle Cirulli of Italy. The game is straightforward. It consists of tiles and a 4x4 board. Multiples of two (2, 4, 8, 16, ...) number is printed on top of each tile. The player can move a tile to another tile, combining them into a single tile whose number is the sum of its previous tiles' number. The movement can only be done vertically or horizontally, and the target is to create a 2048 tile.

Game 2048 is one of the serious games in the board game genre. This paper will explain the building of educational games describing butterfly metamorphosis as a 2048 derivative game. The name of the game is Metamorphosis Edugame. This game was built from scratch instead of including modding games or mod games.

Games can have such a gameplay that players can play with challenges in a situation that permits them to commit errors and reflect on them for further advancement. Games can also be built to motivate players, and to measure the motivation impact toward performance[11]. When players are excited, they put effort to solve the tasks since they enjoy the activities and consider it important.

Metamorphosis Edugame was designed to introduce its players to butterfly metamorphosis process. By playing the game, a player can quickly memorize and know how the process of metamorphosis of a butterfly: starting from egg phase to larva phase, then pupa, and followed by butterfly phase and back again to the egg phase.

II. RESEARCH BACKGROUND

The following is the reason why this research is proposed. One of which is to introduce the metamorphosis phase of the butterfly through educational games.

A. Educational Game

A game can be categorized as an activity that has the following features [12] - [14]:

- Fun: activities that make players feel happy and engaged
- Separation: the activity is constrained in time and place.
- Uncertainty: the result of the activity is undetermined at the beginning
- Governed by rules: the activity has instructions
- Fictitious: There is the awareness that the activity is a different reality.

Metamorphosis Edugame can be categorized as an educational game. It is not a gamification, where developers added game elements, such as game design, game mechanics, and game thinking in non-gaming activities to motivate participants, product [17]. It is also not a game based learning (GBL), where developers encourage players to participate in learning while playing and make the learning process more enjoyable by adding fun to the learning process, product. Fig. 4 shows an example of gamification, while Fig. 5 presents examples of Game-Based Learning.

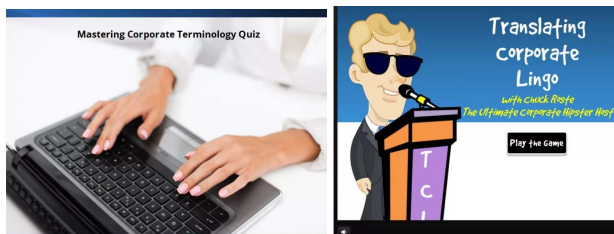


Fig. 4. Gamification: Changing Quizzes to Games[18]



Fig. 5. Game-Based Learning: Minecraft[19] and Sim City[20]

An educational game is a game designed and used with the primary purpose of teaching or learning. A mixture of fun components and educational concepts are used to improve players motivation and immersion [21]. Game use in education has five keys points:

1. Games are built based on sound learning values
2. Games provide more enrichment for the learner
3. Games give personalized learning chances
4. Games teach modern and technologically advanced skills
5. Games deliver authentic and relevant assessment settings

Games have the potential to motivate players to learn. We built 2048 Metamorphosis game in line with the idea in the direction of teaching butterfly metamorphosis phases.

B. Metamorphosis of butterfly

Butterfly goes through a process of metamorphosis in which its young body is vastly different than its mature body. The process has four stages in the metamorphosis of butterfly [22]:

1. Egg. A single adult female butterfly can produce many eggs which are put on plants. These plants' leaves will then become the food for the hatching caterpillars.
2. Caterpillar. The next stage is the caterpillar or larva. The main task of caterpillars is to eat and grow.
3. Pupa. After the caterpillar is grown fully, it turns into a pupa/chrysalis/cocoon. Substantial changes are happening to the larva inside.
4. Butterfly. Butterfly body is immensely dissimilar than larva body. The butterfly's task is to mate and lay eggs.

Metamorphosis Edugame is designed to focus only on the butterfly phase change, and not about the phase details.

C. Model Educational Game

Reference [23] gives several intermingled factors that make games fun:

1. Game Goal. The most fundamental things that other components build upon.
2. Game Mechanism. It is the rules used for the player to accomplish game goals.
3. Interaction. It encompasses players input and game feedback that happens during the gaming session.
4. Freedom. It refers to how many activities players can make in the game and how many features they can use.
5. Fantasy. It is about giving games a proper setting. It includes the game environment and background.
6. Narrative. It describes the information of what is happening in the virtual world.
7. Sensation. It consists of audio, visual effects, aesthetics, etc. that places the player into the virtual world.
8. Value. It is something that attracts players to play the game, such as achievements and awards.
9. Challenge. It is the thing that players must do or solve to make progress in the game.
10. Social Behavior. It is about how the players interact with other players, such as communication, cooperation, competition, and conflict.
11. Mystery. It incites the players' curiosity and thus motivates them to explore.

III. METHODOLOGY

A. Design Model of Metamorphosis Edugame

The game goal is to teach its player about butterfly metamorphosis using puzzle game genre. Displaying metamorphosis phases has the purpose of creating the game fantasy in which the user can imagine the process in real life setting. The challenge is in combining the same metamorphosis

level tiles to produce the butterfly tile. The player wins if he/she can make a 3rd generation adult butterfly tile appears on the board. The game narrative is kept minimal since it is a board game. A score is given each time two tiles of the same phase collide. The players interact with the game by sliding tiles. The pictures depicting metamorphosis stages provides the sensation factor. Because it is a straightforward game, there is not much of game mystery and sociality factor. Achieving 3rd generation adult butterfly delivers game value for the player, encouraging them to play and finish it. Fig. 6 shows the game design model.

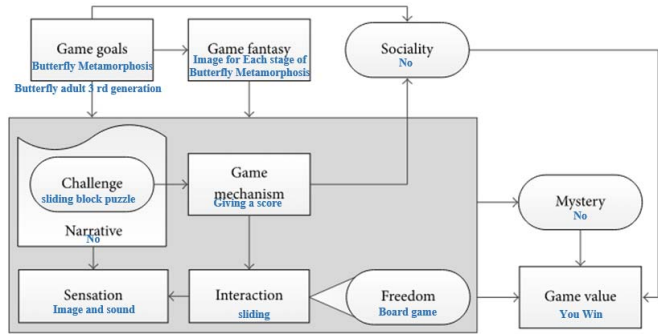


Fig. 6. Design Model of Metamorphosis Edugame

B. Game Rules

Metamorphosis Edugame is played on a 4x4 grid, with images of phase metamorphosis put on tiles that slide smoothly when a player presses four directional keys on the keyboard. Tiles slide can move as far as possible in the chosen direction until it meets another tile or the edge of the grid. Every turn, a new image of either egg phase or caterpillar phase 1st generation appears randomly on empty space on the grid. If two tiles of the same image/phase of metamorphosis collide while moving, they will merge into the next phase of butterfly metamorphosis. The scoreboard at the top continues to update the player's score. The player score starts at zero, then increases when two tiles combine by the value of the new tile. A player wins when a tile with a Butterfly adult 3rd generation appears on the board. After reaching this, players can continue to play to reach higher scores. When the player has no legal moves (there are no empty spaces and no adjacent tiles with the same image), the game will stop. Fig. 7 shows the rule of Metamorphosis Edugame.

Fig. 8 below is a flowchart that describes the scenario of Gameplay from beginning to end game. Some processes will be performed, such as random values and position of occurrence as well as game checks with certain conditions when gameplay is running.

Design of the Navigation Structure of Metamorphosis Edugame which describes the relationship between the scenes shown in Fig. 9.

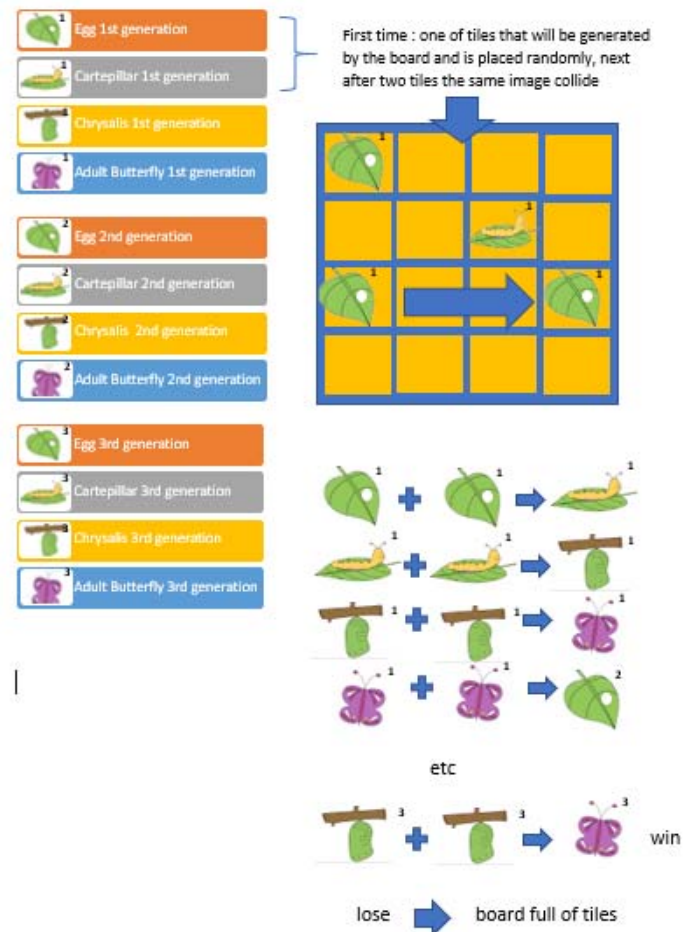


Fig. 7. The Game Rules

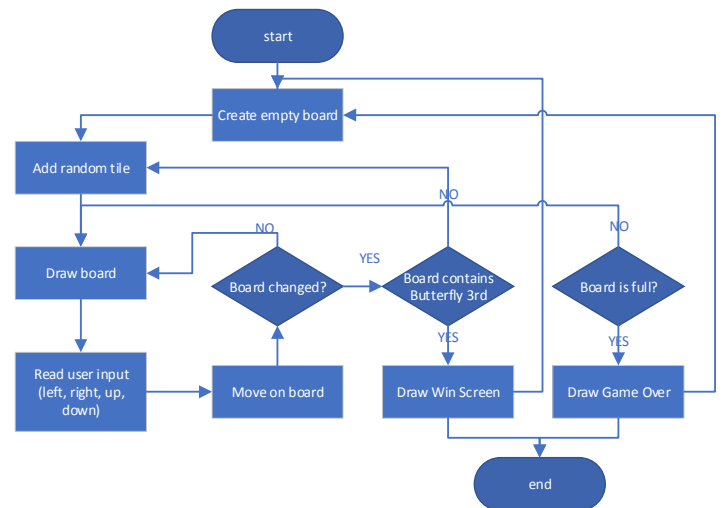


Fig. 8. Flowchart of gameplay Metamorphosis Edugame

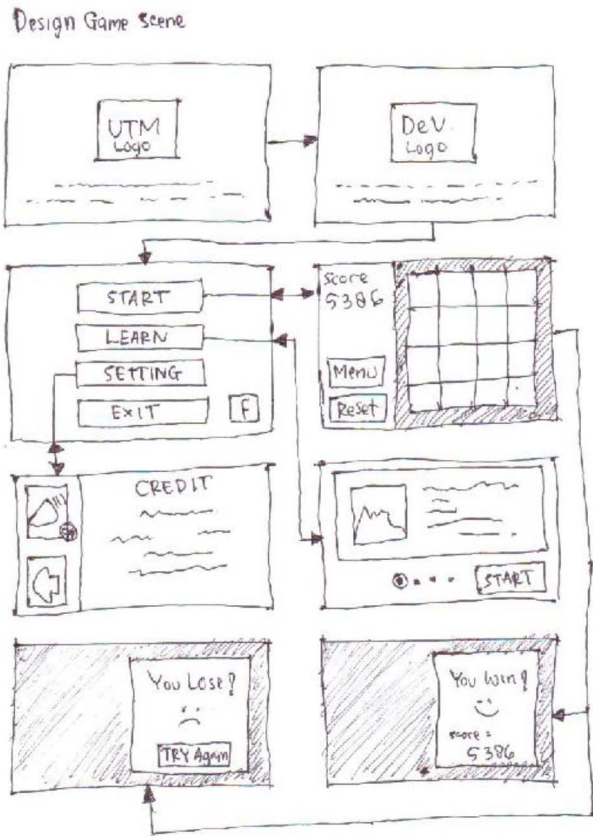


Fig. 9. Design of the Game Scene Relationship

IV. IMPLEMENTATION

This section is about how to construct Metamorphosis Edugame, starting from the game engine which is used in the implementation of the rules.

A. Game Engine

Game Engine is the essence of the game that controls all activities and interactions that occur in the game. Cocos2d-x Framework is the game engine used to build the game. This game is built for Android-based devices.

B. Implementing the game rule

Underneath the phase images, the game uses number representation, so that the tile combining use a simple calculation process; while for presentation, it uses conversion process to translate numbers into images. The conversion table is shown in Table I.

TABLE I. NUMBERS - IMAGES REPRESENTATION

Number	Image	Number	Image
2	1st. Egg	128	2nd. Chrysalis
4	1st. Caterpillar	256	2nd. Butterfly
8	1st. Chrysalis	512	3rd. Egg
16	1st. Butterfly	1024	3rd. Caterpillar

32	2nd. Egg	2048	3rd. Chrysalis
64	2nd. Caterpillar	4096	3rd. Butterfly

A tile with a value of 2 or 4 is randomly chosen each time the player moves the game. Then, the game will check whether there is still a board tile that has not been filled. Afterwards, the computer will decide to display or not the tile. The position in which the tile is placed on the board game is also done randomly by the game.

If there is a collision between blocks with the same value, the game will execute the block merge function. It will delete the two tiles and create a new tile whose number is twice the number of previous blocks. Afterwards, it will then check the blank space on the grid. If there is still an empty space available, then the computer will create a new tile randomly with a value of 2 or 4 and execute the next loop.

Winning condition can be checked by comparing the new Number generated by the collision with WIN_NUMBER constant. The WIN_NUMBER constant is set to 4096 which represents a 3rd generation adult butterfly. Next, the game will show Winning scene. If the new number value obtained from the player is not the same as WIN_NUMBER, winning condition is not reached, and the game will continue to play. If the grid is full of tiles, then the game is over, and the player is declared lost.

V. RESULT AND DISCUSSION

This section explains the gameplay and the experiment results. This test is done to ascertain whether the game can run smoothly and as expected on the device. This test is also used to determine the suitability of the design and the final product. The tests carried out on the real devices, testing the game Graphical User Interface(GUI) on different screen resolutions, the system performance, the functionality of the game component (such as menu, buttons, scene), and user experience testing. Devices used are Oppo A51w, Asus Zenfone 5, Huawei Honor 3c, Xiaomi Redmi 4x, Samsung Star, and Samsung J1. The selection of devices for this trial is made randomly.

A. Gameplay scene

Display user interface of Metamorphosis Edugame during gameplay is presented as shown in Fig. 10.



Fig. 10. User interface of Metamorphosis Edugame

B. Functional Testing

The Functional Testing is done to find out whether the menu system, button, and scene are built by design. Table II shows the results.

TABLE II. FUNCTIONAL TESTING RESULT

No	Device	Status
1	Oppo A51w	Working
2	Asus Zenfone 5	Working
3	Huawei Honor 3c	Working
4	Xiaomi Redmi 4x	Working
5	Samsung Star	Working
6	Samsung J1	Working

Working status on table II means that all button, scene, and the menu work as it should.

C. Gameplay Testing

The trial was conducted on the six devices to determine whether the gameplay rules are built by the rules that have been decided in the design stage. Table III shows the results.

TABLE III. GAMEPLAY RESULT

No	Device	Status
1	Oppo A51w	Support
2	Asus Zenfone 5	Support
3	Huawei Honor 3c	Support
4	Xiaomi Redmi 4x	Support
5	Samsung Star	Support
6	Samsung J1	Support

Support status means that the design stage rules are correctly implemented in the final product, form starting to winning stage according to the gameplay scenario.

D. Graphical User Interface Testing

Graphical User Interface testing is conducted to see whether the designed interface can adapt to different screen resolutions. The result is presented in Table IV.

TABLE IV. INTERFACE TESTING RESULT

No	Device	Status
1	Oppo A51w	Proportional
2	Asus Zenfone 5	Proportional
3	Huawei Honor 3c	Proportional
4	Xiaomi Redmi 4x	Proportional
5	Samsung Star	Proportional
6	Samsung J1	Proportional

Proportional status means that the position of the background, buttons, title, and assets are proportionally placed on different screen resolutions.

E. End User Testing

The trial was conducted on 15 people, divided into three groups: children, adolescents, and adults. Each level consists of

5 randomly selected people. The trial is done using one of the six devices. For each group, the average value was calculated for later inter-group comparison. Table V, VI, and VII show the result of each group.

TABLE V. CHILDREN (5-12 YEAR OLD) GROUP RESULT

No.	Name	Age	Score
1	Nofal	9	3040
2	Aril	9	1368
3	Tio	7	2640
4	Azam	6	5776
5	Mila	5	2644
Average			3093.6

TABLE VI. ADOLESCENT (13-17 YEAR OLD) GROUP RESULT

No.	Name	Age	Score
1	Icha	17	6456
2	Rifdah	17	7624
3	Alfin	17	4916
4	Fani	16	5140
5	Sela	17	1700
Average			5167.2

TABLE VII. ADULT (MORE THAN 18 YEAR OLD) GROUP RESULT

No.	Name	Age	Score
1	Siman	27	1144
2	Rifki	21	6504
3	Hojir	22	3620
4	Fariz	25	6708
5	Nita	26	6612
Average			4917.6

The score value as the test data game since the game does not have the maximum score for a player. The higher score means, the better the player is; thus, the score can be used to compare the players.

From Table V, VI, and VII, we can see the average value for each group: 3093.6 for children group, 5167.2 for the adolescent group, and 4917.6 for the adult group. We use a simple equation to find group percentage using (1).

$$\text{Percentage} = \frac{\text{Average Value per Rankings}}{\sum \text{Average Value of All Levels}} \times 100\% \quad (1)$$

The percentage value of each group is 23.47% for children, 39.21% for adolescent, and 37.32% for the adult group. It can be concluded that the user with the highest playing ability is adolescent and the lowest is children group.

VI. CONCLUSION

Metamorphosis Edugame is designed and created by the game design rule of 2048. This game runs well and optimally on Android devices with 512 RAM. This game also works well

for devices with Android version 4.1.2 (Jelly Bean) up to the latest version. Device specifications affect the speed of the computer in responding and making decisions.

Cocos2d-x can be applied to the Metamorph game as a framework for the game engine that works to manage all game controls.

Experimental results showed that adolescent and adults could play the game well, but not so for children. The user with the highest playing ability is adolescent, and the lowest in children group.

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