

Mobile Game Design for Learning Chemical Bonds with Endless Run Approach

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Muhammad Hafis^(✉), Ahmad Afif Supianto
Brawijaya University Malang, Jawa Timur, Indonesia
akhiahmadhafis@gmail.com

Abstract—This research focuses on the design of a mobile application game that uses endless run method to learn chemistry concept of chemical bonds, its design is analyzed thoroughly. Application-based learning is one of the method of learning that has been proven to be effective, however, previous studies focuses on the elements of serious gaming that neglects the fun elements in the game itself, disdaining the nature of a game. This research aims to expose and elaborate the idea of learning chemical bonds by using mobile game approach with an addition of data gathered from players for learning and analysis purpose. The functional analysis for the game design are also stated to reinforce the idea validity.

Keywords—application-based learning, chemical bonds, educational games.

1 Introduction

Currently the field of application-based learning is one of the emerging fields of study in the domain of mobile application development specifically in game-based mobile applications [1]. Application-based approach can be used as a proper approach for educational purpose as the aforementioned approach has shown a significant positive effects on learning, the amount of time spent playing educational games scales linearly with student's attitude towards learning [2], in term of the device used, games developed on mobile devices shows more flexibility and potency as a field of research and development [3].

One of the field of science that can be improved by using the mobile game approach is high school chemistry subjects [4] due to the difficulty from the students to understand the concept conventionally and lack of interest by the student to explore the subject in details. [5], another reason is due to the level of illustration required by the student to visualize the concept and interactions between objects in chemistry requires some level of abstraction, mobile application-based approach are able to provide a relevant level of user experience while also provide a proper interactions required for such needs [6]. In the high school subject of chemistry, one of the earliest chapter learned that require a high level of abstraction is the concept of chemical bonds, where the relationship between two or more chemical elements forming a compound is learned.

The approach of using mobile games to teach chemistry has been done in several ways and for several subjects [7], [8], [9]. However the recent works uses the concept of serious games which focuses on the effectiveness of the game itself while neglecting the fun element of the game itself, removing the very essence of the nature of a game itself.

This research suggests an approach of a mobile game that uses endless-run concept to convey the fun element due to this type of game has shown a relatively high level of fun while also engage the player with a challenging content [10]. The concept of endless-run itself is a form of game where the player controls a main character that runs in an environment endlessly until a certain condition is reached [11].

2 Theoretical Background

The concept of game-based learning being used to improve student's comprehension on a particular subject has been proven to be relevant, either in form of mobile applications, or traditional method such as board games [12] or card games [13]. The rigid and abstract but structured nature of the subject of chemistry is one of the main reason why game-based approach is a relevant method to be implemented by using a mobile device, as it is able to improve interactivity and visualization due to the nature of mobile device, furthermore, game-based approach on mobile device also known to be able to improve student's passion towards learning in general [14].

In game-based approach, several concepts of game design can be implemented to be able to integrate with the field of chemical bonds, the concept of collectibles is introduced and implemented, an action of a character controlled by a player to collect items inside the game for a certain amount to be used for a certain goal, either to finish a mission, gather more advanced objects, or get in-game points [15]. The concept of object visualization on chemical bonds field is used to improve the traditional method of card and pictures which is proven to give a positive impact towards student's understanding [16], [17] by using a mobile device which has far better capability in delivering dynamic objects compared to conventional approaches.

The chemical bond concepts are visualized directly by creating an in-game object to represent such chemical elements, along with collectible concept, the chemical elements can be collected and gathered with a certain mission to be given to the player as an engaging element of the game.

In-game missions are crucial for the player as it gives the player a reason to finish a certain action and acts as a scenario that drives player's motivation to play the game despite of the theme, giving the player a chance to think about a strategy to finish such given mission, this approach is compatible with the educational strategy that guides the student to understand a concept by using a mind map [18].

By using the combinatory approach, a gameplay can be created by using the endless-run concept, a combinatory approach that mends together several concepts is created, driven with an endless-run game format. Chemical compounds are formed with a certain combination of several chemical elements, chemical elements can be used as collectibles while chemical compounds are used as a mission, the number of chemical

elements in a certain chemical compound formula are set as a goal and the method of gathering is driven in form of endless-run game. The objects are then visualized on a mobile device in form of a mobile game.

Data log is one of the additional aspect in game design that allows the developer to learn and elicit information from the player and learn their behavior to create multiple analysis and improvements [19]. As an additional aspect, it is not compulsory, but instead allow the game to be developed and change based on player's activity, creating a better improvements overtime. The data log also promotes data analysis for educational purpose and convenience [20] which allows the developers to create visualizations and learn hidden aspects of player behavior such as trap states and players tendency to fail or misunderstood a particular game mechanics.

3 Design

3.1 Design Concept

Based on the background problem and theoretical background domain of problem, a design concept is proposed by using bottom-up approach that puts the foundation on controls rather than the actual big picture itself as depicted on Fig. 1, starting from character controls, to game mechanics, to feature and contents, and a story to convey such setup into a relevant concept of a game.

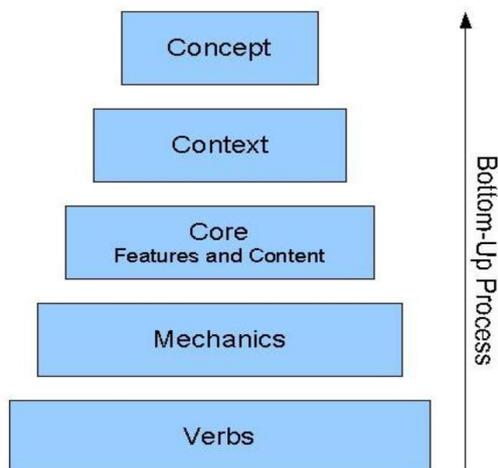


Fig. 1. Bottom Up Process of Game Design

Control and mechanics of the game are designed to ease player's achieving a particular task, the control proposed on this design concept is the ability to jump. In term of accessibility, the user's control is by tapping the bottom half of the screen. Endless run

games tend to have simple controls to promote intuitiveness and ease the amount of time spent on learning to minimum, making it suitable for all type of users.

Game mechanics are the rules set by the game to limit and control player's action, as such, the cause-effect relationship and consequence of how the in-game world works are defined to match the concept of endless run games. The proposed game mechanics puts the main character to be controlled by the player by tapping the screen of the mobile device and the control is limited to only jumping. The action done by the player inherently and automatically is defined as running on a horizontal space from left to right, the jumping action is defined to be a parabola movement done by the player from one point to another while the scene is moving on a repeated pattern – showing as if it is an actual endless scene. Another form of action done by the player is collecting items which happens when player collides with an in-game object of collectible elements.

Collectibles are defined as chemical elements scattered on the scene of the game and is meant to be collected by the character as a defining action of the game missions and is procedurally randomly generated throughout the scene. Mission is given by the game in form of chemical compound names (but not its chemical name), designed to be the objective of the player during the game commences, the number of chemical elements gathered are also set based on the chemical compound on a particular playthrough.

Obstacles are defined as objects that obstructs the movement of the character controlled by the player, there are two types of obstacles, static and dynamic, which static obstacles halts the player movements while the latter stops the game immediately.

The main feature of the game as it incorporates the fun elements of a game in contrast to existing serious games, giving it a novelty in term of approach, by using the concept of object visualization, the elements and its relationship with other elements can be represented properly, giving the player an idea of how chemical elements may interact with each other.

The context of the game is set to control the mechanics of the game, proposed context focused highly on the concept of the chemical bonds in this game and how the collectible and mission interacts with each other. The main context sets that the collected elements may be gathered as many as the player wants but the compound given also changes dynamically as the player gathered too much of a particular element. As an example, a compound given as a mission is water (Chemical name: H_2O) which requires 2 Hydrogen elements and 1 Oxygen elements, as the player collects the elements during its playthrough, once the player gathered 2 Hydrogen elements, the player can end the game easily by collecting 1 Oxygen atoms, but unsuspecting player can accidentally or unknowingly collects an extra Hydrogen element, thus making the amount of elements gathered to be too much, the game context controls this by doubling the amount of mission chemical compound into 2 H_2O , which results in the player to get another Hydrogen element while adding an extra Oxygen, making a grand total of 2 Oxygen elements. This goes on as the player collects to much of a single element, thus creating the player to develop a strategy of skipping Hydrogen elements once the element gathered is enough and focuses the Oxygen elements more. Fig. 2 shows a tabular form of the collectible and mission relationship game mechanics.

Mission: Form Any amount of H ₂ O					
Required Elements: H = 2 O = 1, or any of its multiple.					
H \ O	0	1	2	3	4
0	x	x	O x2	O x3	O x4
1	x	x	O x2	O x3	O x4
2	x	H ₂ O	O x2	O x3	O x4
3	H x2	H x2	O x2	O x3	O x4
4	H x2	H x2	2 H ₂ O	O x3	O x4
5	H x3	H x3	H x3	O x3	O x4
6	H x3	H x3	H x3	3 H ₂ O	O x4
7	H x4	H x4	H x4	H x4	O x4
8	H x4	H x4	H x4	H x4	4 H ₂ O

Context:
 x = mission has not reached
 [a] | x[b] = element [a] is overflowed, mission is multiplied by [b]
 [a] [b] = [a] amount of [b] has been created, mission is over.

Fig. 2. Game Mechanic Tabular Form

On the data log analysis, the log keeps tracks of the elements gathered by the player and how the mission changes, such that the game analysis would focus on the trap states of how the player learn what elements should be gathered and how much such element would be gathered. The same log data also will be able to analyze the tendency of failure, whether it is because of the game missions, or the spawn rate of a particular elements is too disproportionate, or the core game mechanics that is too hard to be played.

3.2 Use Case Diagram

The use case diagram is used to show the degree of freedom that the player has the control upon playing the game. The player is able to start the game and then proceeds to choose the level, view the leaderboard or exit the game.

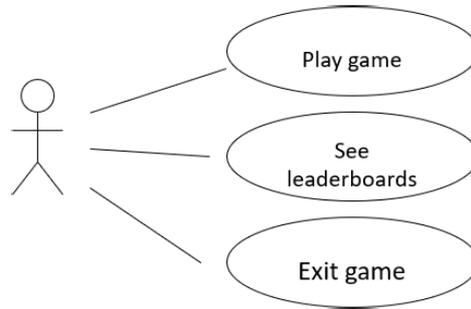


Fig. 3. Use Case Diagram

3.3 Gameplay Design

The main flow of the gameplay is designed to be linear, goal-driven, and interruptible by obstacles, the gameplay common example is depicted in the following pseudocode on fig 4.

The game starts by initializing game scene, scores, and objects, the positioning and objects changes based on the level chosen by the player, the mission is also adjusted by the level chosen. If the player hits an obstacle, the game ends and calculate whether the high score is reached or not. If the player collects an element, it is compared and if the amount exceeds the mission elements, the mission elements is doubled. If all elements gathered reach the mission, the game ends and calculate the score and opens the next level.

```
egin
  Initialize: level set, currentScore, highScore, scene;
  Choose level;
  Initialize Mission.level, element.n_amount, ele-
.n+1_amount;

  While (player state = alive)
    score++;
    IF (player hit obstacles)
      End game;
    Compare currentScore and highScore;
    End If

  For j = 1 to n (where n is the total number of
different elements)
    IF (element.j_current > element.j_amount)
```

Fig. 4. Pseudocode of Common Gameplay.

4 Analysis

4.1 Functional Analysis

Functional analysis is done by using black box method by testing whether the game can run well or not. The analysis set is depicted on table 1.

Table 1. Example table

No.	Components	Expected Result
1.	Play button	The player is able access the play button to start the game.
2.	Leaderboard button	The player is able to access the leaderboard button.
3.	Choose level button	The player is able to choose level to play.
4.	Pause button	The player is able to pause the game during gameplay.
5.	Resume button	The player is able to resume the game after being paused.
6.	Return button	The player is able to return to the main menu during gameplay.
7.	Jump button	The player is able to jump by pressing the bottom half of the screen.

5 Future Works

Future works of this study will focus on the design and development while also focuses on the analysis of the result of aforementioned gameplay while improving the details of the game itself.

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7 Authors

Muhammad Hafis is a master student of the Faculty of Computer Science Brawijaya University, Malang, which takes the multimedia, games, and mobile focus.

Ahmad Afif Supianto is a lecturer at the Faculty of Computer Science Brawijaya University, Malang, for the field of multimedia, games, and mobile focus.

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