Developing An Educational Game for 10th Grade Physics Students

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ABSTRACT
An educational game could be used to attract high school students of learning their subjects. This research is focusing on developing a game for 10th grade physics students, especially on Physics Rectilinear and Circular Motion, Newton's Laws of Motion, Geometric Optics, Electrical Dynamics, and Electromagnetic Waves. This game has a storyline on physics lessons. The game is developed using the programming language ActionScript 2.0 and Flash as a local shared object storage media. The end result of this game is a game-based education, which is equipped with the learning board, saving, and loading features. The software is also tested on several different types of computers. The comparison showed that this software can be run well with any standard computer specification.

Keywords
Education Game, Physics, ActionScript

1. INTRODUCTION
The gaming industry is developing rapidly with a variety of genres. The development of the game is influenced by the increasing technological advances resulted in more and more sophisticated games. Based on the results of questionnaires carried out to high school students, it turns out that most of the respondents have difficulties in learning physics because the lack of learning tools. Previous researches have already developed similar games for examples Crayon Physics, World of Goo, and Mifas Adventure; therefore this research combines the favorable games among them.

Features	This game	Crayon Physics	World of Goo	Mifas Adventure
Save game and load game	Yes	Yes	Yes	No
Game explanatory	Clear	Not clear	Not clear	Clear
Degree of difficulty	Average	High	High	Easy
Interface design	Average	Good	Good	Not good

Previous works have already showed the benefit of learning with ICT especially computer games [1] [2].

2. COMPUTER GAME
Computer game is a game played through the aid of computer tools [3]. Computer game is different from other types of games because there is no physical movement or direct interaction with the object except through the medium of the computer. Software must be able to capture the rapid reaction from the interaction between players. The complexity of the game depends on the ability to represent rules and game environment created in the program.

3. PHYSICS THEORY
Some of the theories used in this game are described below.

3.1 Motion
Motion is a change in the position of an object against its surroundings [4] as bellow:

1. Transfer

The position of an object is determined by a line called the axis of coordinates x, where the line is used as a reference point. The value of the displacement of an object depends on the direction of motion. The object displacement is positive if the motion direction moves to the right object. The object displacement is negative if the motion direction moves to the to the right.

2. Velocity

Velocity is a vector which is determined by the magnitude and direction. The velocity of an object is using the following equation:

$$v = s / t \quad (1)$$

where: v = velocity (m / s); s = displacement (m); t = time (sec)

3. Acceleration

Acceleration is a vector which is determined by the value addition. It is also determined by the direction of displacement. The magnitude of the acceleration equation is using the following equation:

$$a = v / t \quad (2)$$

where: a = acceleration (m/s2); v = final velocity (m / s) t = time for the velocity change (sec)

3.2 Newton's Law of Motion

Every object persists in its states **of rest or uniform** motion in a straight line unless it is compelled to change that state by forces impressed on it [4]. This can be formulated:

$$F = m * a \quad (3)$$

where: a = acceleration (m/s2); F = net force (Newton); m = mass (Kg)

3.3 Geometric Optics

Image formation can occur due to a reflection at the mirror which can be divided into flat mirrors, concave mirrors, and convex mirrors [5].

Flat mirror has a reflectivity of law which the angle of incidence equal to the reflection angle. Therefore the two angles are of the same height. The assumption is h is the height of the object and the high point of the t is t = ½ h. Flat mirror also has properties of virtual image and the object distance is equal to the distance between the image and the mirror

Concave mirror is also called convergent mirror. Concave mirror is divided into 4 rooms in the shadows and object placement, where R is the radius and f is the focus, where f obtained from the half of radius. Forming mirror images can be obtained from the special light in the mirror. The first special beam axis is parallel to the primary and will be reflected through the focus. The second one is towards the focus and reflected parallel to the major axis to find intersection. The third one is a special beam of light towards the radius.

Convex mirror is also called diverging mirror. Just like a concave mirror, convex mirror is also divided into 4 rooms. The intersection of the light creates a shadow, so the virtual image will be scaled up. The distance from the mirror to the object called s, while the shadow to the mirror is called s'. The connection between s, s', and f is 1 / f is 1 / s + 1 / s'.

3.4 Electric Dynamic

Electricity is a flow of charge through a point per second, which can be determined [5]:

$$P = V * I \quad (4)$$

where: P = power (watt); V = voltage (volt); I = the current (amp)

3.5 Electromagnetic Waves

According to James Clark Maxwell, electromagnetic waves occur due to the changes in the magnetic field may cause an electric field. The amount of electromagnetic wave is formulated as follows [5]:

$$c = f * \lambda \quad (5)$$

where: c = velocity of propagation ($3x10^8$ m/sec); f = frequency (Hz); λ = wavelength (m)

4. GAME DESIGN

The title of this game is "School Day: Bring Back the Genius", which is an education game with a small town setting. The following sections will explain the game's design.

4.1 Environment

The game is in the form of a world map. There are pictures of a home, park, school, museum, garden and the menu menu. The games can choose any of the building to start playing. The menu button consists of choices to Resume, Save, Back to Menu, or Exit. Home is the place where the game begins and the main character gets a mission to accomplish. In this story, home is where the main character lives with his mother. School is the place where the main character can learn, talk to the teacher and her friends (Steven and Cindy), and also can read theoretical physics when talking with the teacher. A garden is the place managed by Toni (the gardener). The main character and his friends can get extra lessons from their teachers in the form of a mini game. Nevertheless this garden also contains missions to be completed. Museum is the place where the main character can see histories of the physicist which is guarded by a security guard. The main character and his friends can get extra lessons from their teachers in the form of a mini game. The flowchart of the game can be seen in Figure 1.

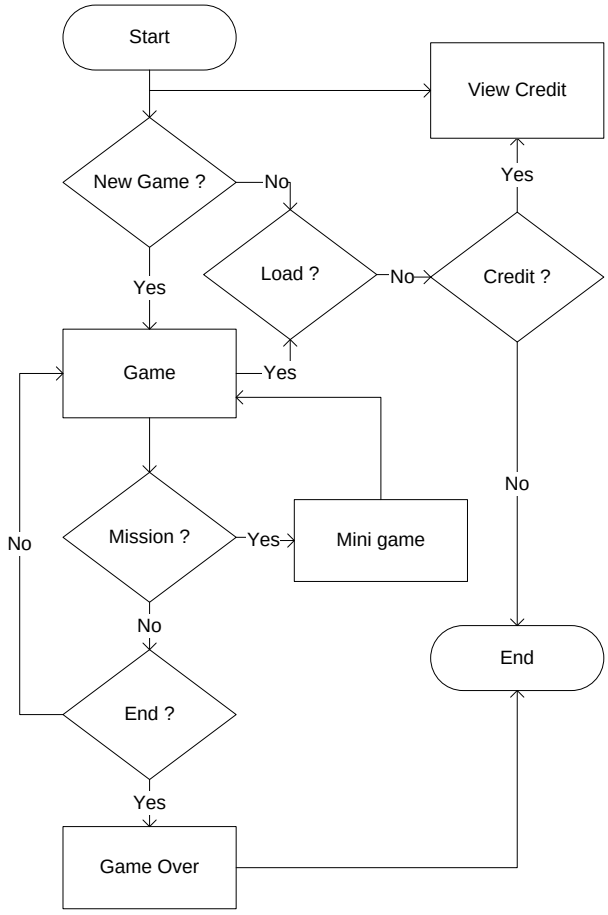

Figure 1. Game Flowchart

4.2 Characters

The characters of the game consist of:

1. Main character (Doan)

Doan is the main character in this game. He is a genius but he wastes his time with playing during his junior high school years.

Therefore people around him assume that Doan is not responsible. Doan wants to prove that he is not like what other people think. Therefore Doan wants to change his behavior when he enters senior high school.

2. Rival character (Steven)

Steven is one of the main character's classmates, who has a passion and desire to learn. Since junior high school, he is always top ranking student in school. Therefore he does not like making friends with his classmates who are considered lazy (one of them is Doan).

3. Friend (Cindy)

Cindy is one of the main character's classmates; Cindy is a person who likes to help her friends and has a high enthusiasm for learning. Cindy is not smart as Steven, but she is liked by her classmates.

4. The teacher

The teacher is a teacher who teaches Physics at the main character's class and loves all the students.

5. The gardener (Toni)

Toni is a gardener who is 30 years old. Toni has a desire to develop his garden so that much greater.

6. Security (Erick)

Erick is a guard at the museum who is 22 years old who likes to hang out and learn about history.

7. Mom

The parent of the main character who always gives advice to her son, and hopes his son could change his lazy.

4.3 Stories

"School Day: Bring Back the genius" is an educational game that tells about a boy named Doan who lives in a small town. This story begins on the first day of school when Doan is too late to get up to go to school. When he arrives in school, the teacher gives an introduction and explanation of the motion lesson and illustrates with mini game format (Figure 2). The next day the teacher chooses the president of the class and provides an instruction from the principal to all students to conduct community service in the dirty school environment. Figure 3 represents a game played by Doan when he assigns at the warehouse and surprises by a mouse. Doan and friends are trying to catch the mouse. This game is teaching about the physics lesson on motion. After cleaning the warehouse pack, the teacher explains the Newton's Law of Motion lesson. The teacher advises the students to do extra studies with choices go to the garden (Figure 4) or go to the museums (Figure 5) to replace the time spent for cleaning the school.

The next day, the teacher gives an explanation of geometric optics lesson. Doan must be working on an assignment, which represent by Figure 6.

The teacher will announce the result in the next day. If Doan get more than 80 points then he will be the student who has the highest points. If the score under 80 points, the teacher will advise Doan to study harder. That day, the teacher gives a lesson about electric dynamic. After school, Doan's friends invite him to study together in the park and he must do the electric power mini game.

The next day, the teacher teaches electromagnetic waves lesson by asking questions in class (Figure 7).

The next day is the announcement day where the game is ended. There are 3 kinds of ending point: more than 80 (good), more than 60 and less than 80 (average), and less than 60 (poor).

5. GAME IMPLEMENTATION

5.1 Motion Mini Game 1

The player must answer the speed of the bus (motion) by observing the animation of a walk around the city bus with a speed and distance. If the player answers correctly then he will get 20 points; whereas if the user answers to a range of -2 and +2 correct answer he will get 10 points, otherwise the player get no point. The mini game in Figure 2 uses equation 1. With time is 135 s and distance 8000 m, than v is 59.259 (round to 59).

5.2 Motion Mini Game 2

The player is given an animation of a rat that ran with the speed and erratic. The player should be able to catch the mice with estimating the speed of the mice (motion). If the user is able to guess correctly then he will get 20 points, if the user guessed the wrong answer before time runs out he will get 5 points, otherwise he will get no point. The mini game in Figure 3 uses equation 1, where v = 8 m/s and t = 22, so it results s = 176 m.

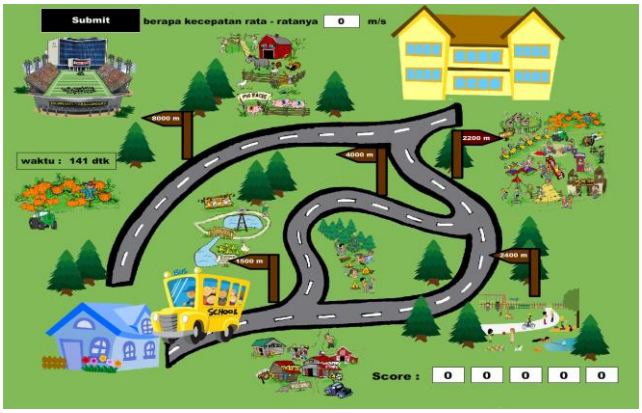

Figure 2. Motion mini game 1

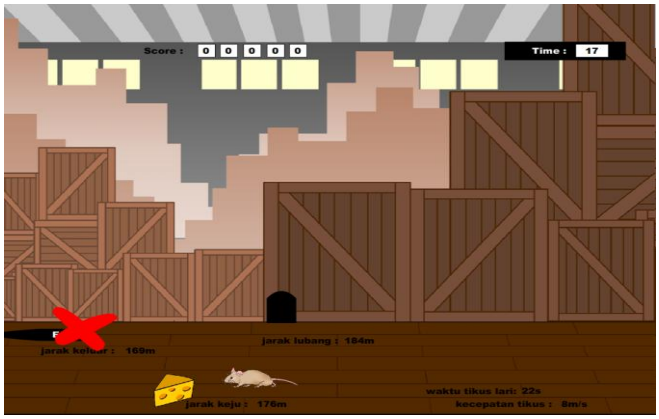

Figure 3. Motion mini game 2

5.3 Newton's Law of Motion Mini Game 1

The main character is pushing an object with a certain weight and fields that the user must press a key / mouse to determine the thrust force (Newton's law of motion). If the user managed to push the object with a range less than 1 m and -1 m more than the destination then he will get 20 points. If the range is less than 2 m and more than -2 m then get a value of 15, less than 3 m and more than -3 m get 10 points, less than 4 m and more then -4 m get 5 points, else gets no point. The mini game can be seen in Figure 4.

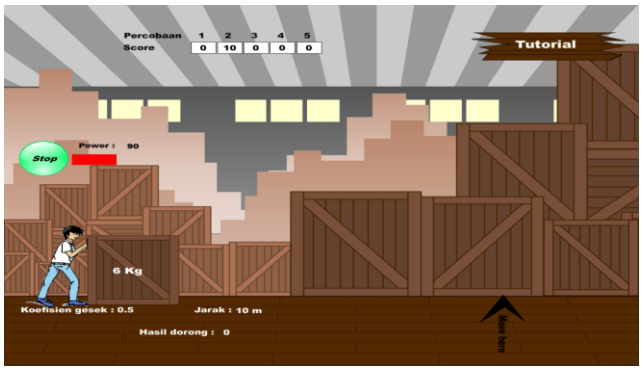

Figure 4. Newton's law of motion mini game 1

Equations uses for this mini game are w (weight) = m (massa) * g (gravity), Fg (friction) = μ (coefficient of friction) * N, s = v0 * t + (1/2) * a * t^2, W = F * s, F = F – Fg, and F = M * a. The step will be w = m * g (6 * 9.8) = 58.8, Fg = μ * N (0.5 * 58.8) = 29.4. The next step is find a with F - Fg = m * a (90 - 29.4 = 6 * a), a is resulted 10.1. s = v0 * t + (1/2) * a * t^2, for v0 = 0 and t = 1 then s = (1/2) * a * t^2, s is resulted 5.05 (round to 5 m).

5.4 Newton's Law of Motion Mini Game 2

The player must be able to estimate the braking acting on the plane with examine the certain mass, speed, and distance of the plane (Newton's laws of motion). If the user managed to land on the runway then the player will get 20 points. If the player landed within range of 10 m, the player will get 16 points, if the range within 20 m the player will get 10 points, and otherwise the player gets no point. The mini game can be seen in Figure 5.

Figure 5. Newton's law of motion mini game 2

This mini game also uses equation vt2 = v02 - 2as (vt = 0) in order to find s. For m = 15 ton, F= 8 * 105, v0= 97, then a = 800000 / 15000 (F = m * a) = 53.33. S = v02 / 2a (s = 972 / 53.33 * 2) = 88,214 (round to 90 m). Total distance will be 90 (initial distance) + 90 (braking distance) = 180.

5.5 Geometric Optics Mini Game

Given an animation of an object with a certain height and distance with a mirror in the middle, there is an object that also has some distance to the mirror and the user must calculate the distance of the shadow of the second object when viewed from a height on the first object (geometric optics). This game has 5 questions. If the player answered each question correctly then the player will get 20 points, if the range of 3 to -3 difference with the correct answer then the user will get 10 points, if the user answered outside the range that has been provided then the player will not get no point. The mini game can be seen in Figure 6.

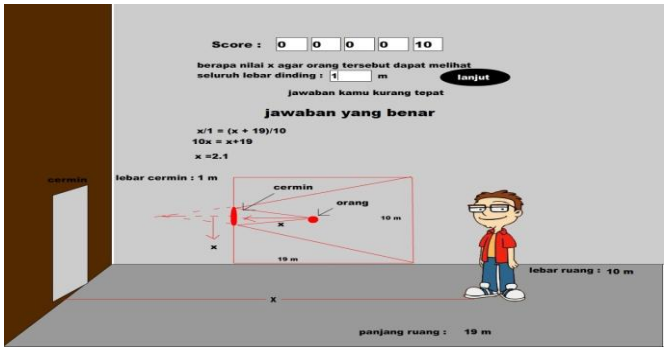

Figure 6. Geometric optics mini game

5.6 Electric Dynamic Mini Game

There is a room which is equipped with electrical appliances. This mini game uses equation 4. The player should switch on/off for each appliance in order to fulfill the potential switch. The maximum score will be 100 points, but when there are appliances which should not be switched, than the score will be reduced. Figure 7 shows the V is 500 volt and the I is 5 amperes, it means the room can only use 2500 watt power.

5.7 Electromagnetic Waves Mini Game

A radio station has a specific wavelength and the player must calculate the right frequency (electromagnetic waves) to receive the signal. This mini game uses equation 5. The player must determine the right frequency before the time runs out five times. Every time the player answered correctly then he will get 20 points, else he will get no points. The mini game can be seen in Figure 8. The mini game shows the wavelength is between 273 m and 373 m while c is $3*10^8$ m/sec. The frequency at 273 m is 1098.901 khz while the frequency at 373 m is 804.289 khz. The right frequency for the radio station is 804.289 - 1098.901 khz.

6. CONCLUSIONS

Application is capable to model physics in the form of game. This game is able to attract high school student to study the whole material by finishing the story. Save and load process in this application uses local shared object.

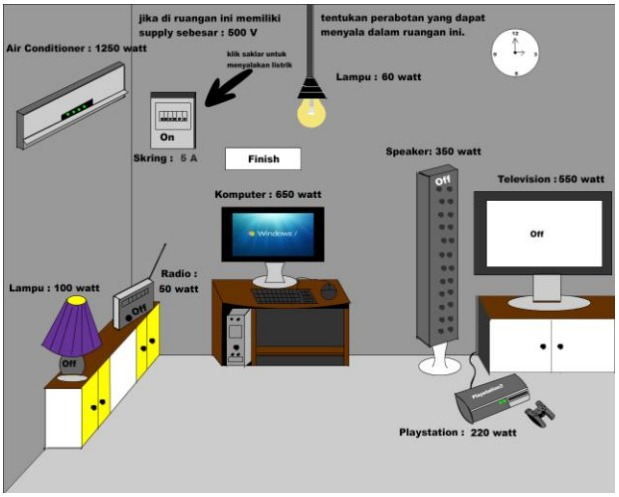

Figure 7. Electric dynamic mini game

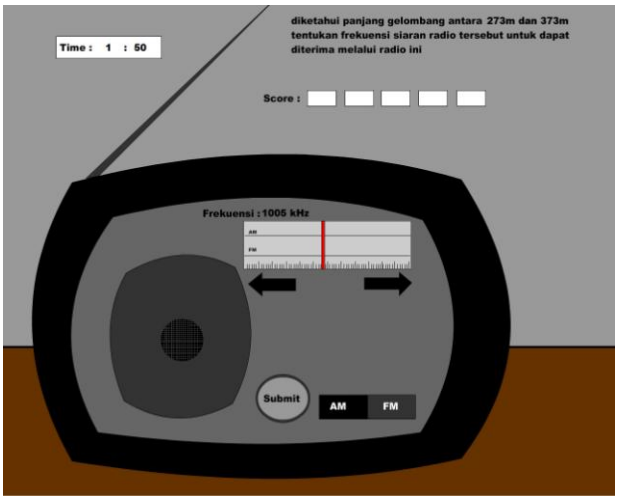

Figure 8. Electromagnetic waves mini game

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