

# Proposal and Development of a Computer Game for Teaching Physics

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## Abstract.

Nowadays, educational games have been used for teaching. Researches show the benefits of its application in the learning process. Thus, this meta-paper aims to present a brief summary about the development of a learning object for physics teaching. It consists in a computer game that simulates a billiard game and, while playing it, the user may learn about the physics formulas applied.

**Keywords:** Computer Game, Learning Objects, Physics, Education

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## 1. Introduction

There is a lot of discussion about the traditional education system based on the master's speech. This topic is strongly linked to its unidirectional rhythm and to the inert role assumed by the learner, looking at the board, listening to recitations, copying and occasionally testing his performance and learning. The historical weight of a model like this usually demarcates also online classrooms, which prevail in the operational mode focusing on the performance of the teacher, responsible for the production and distribution of packages of "knowledge".

Both in the traditional way, and in digital and online media, what prevails is the underutilization of technologies and devices that emphasize interaction and generation of experiments. On the other hand, in their day by day, this same student, connected individual, experience concepts, content and information from a variety of interactions afforded by the Information and Communication Technologies through various devices. This new form of experience ends up pushing non-formal learning further away from that practiced in the schools.

In order to bring together the informal experiences of learners and the formal education, and to deal with complex concepts in a more ludic way,

emerges at the end of the twentieth century, the concept of Learning Objects (LO), digital resource designed for educational purposes to assist the learning [Wiley 2000]. These objects may be a single activity or even a complete educational module [RIVED-International Network of Virtual Education 2012] used both in classroom education, and in hybrid or at distance models. In this sense they can satisfy various fields of work such as formal, corporate or informal education.

Dynamic, interactive and reusable, according to Fontana [2011], the LOs may consist of various types of media - videos, music, images, animations, graphics, educational games, web pages - individually or combined, with the purpose of assist the learner to assimilate the concepts worked. A substantial number of educational software currently available is presented in the form of games [Becker 2001]. Its great advantage is the fact that the learner can build knowledge through a resource that offers dynamic and entertaining interactivity to the player, holding his attention and instigating learning. This relaxed manner makes learning objects that are constituted as games become excellent tools for skills and strategies process. The game allows the user to establish opportunities to find solutions and interact with the environment, providing the rational and cognitive development of various skills.

At the beginning of the century, the progress of computer technology improved the resources available for software development, allowing educational games to be built with greater level of details and functionalities, so that its educational skills would be really important, and often even superior to the traditional way of teaching. Another major factor was the growth of the Internet and its accessibility. Educational content can now be accessed not only through the use of PCs, but also tablets, phones, and any other tool / instrument that has Internet access, bringing the possibility of learning from anywhere, anytime.

Currently, the advance of programming platforms and computational resources enables new educational games to be programmed in a creative and interactive way, such as using touch-screens instead of mouse and buttons, allowing, for example, the simulation of mechanical movements, such as pulling a rubber band or pushing a ball. Such

activities can attend as examples in a physics class, making it more "attractive" to a student.

Thus, the aim of this work is the proposal and development of an educational game as a learning object for teaching Physics. The goal is to simulate a billiard game and the physics of collision, force and trajectory involved in it.

## 2. Physics in the Billiard Game

Education is realized in different forms. With regards to formal education, ranging from traditional classroom education, passing through the one supported by the technology and getting to other totally at distance. "The level of use of ICTs (Information and Communication Technology) depends largely on the technological infrastructure available (such as bandwidth and disk space), the human capacity to deal with the technologies, and also the educational goals proposed" [Filatro and Piconez 2004].

In education using ICTs, the instructional design is dedicated "to plan, prepare, design, produce and publish texts, images, graphics, sounds and movements, simulations, activities and tasks anchored in virtual media" [Filatro and Piconez 2004].

In this sense, Filatro and Piconez [2004] point out that instructional design models tend to structure the planning of teaching and learning in four major stages or phases:

- Analysis: identification of learning needs, the setting of instructional goals and the gathering of the restrictions involved;
- design and development: planning of instruction and preparation of instructional materials and products;
- implementation: when you give the training and ambiance of teachers and students to the proposal of the instructional design and execution of the event or situation of teaching and learning;
- evaluation: monitoring, review and maintenance of the proposed system.

Thus it was necessary to search for concepts of Physics that for the students were difficult to understand and to propose the relation of these principles with some everyday situation. The relation chosen was the Physics with the billiard game.

Costa [2007] says that a billiard player who has a good knowledge of Physics is able to design a play and its outcome in his mind, because he understands how the Physics's calculus of force and motion of bodies work. During a gameplay, several formulas of Physics must be applied to explain the

actions and results of play. As an example, the first strike in the white ball, the collision between the white ball and (s) other (s) ball (s), the collision of the ball (s) with the wall of the table, until the final movement of the last ball that is moving.

According to the website Educare [2012], when the first strike happens, the player applies a force  $\vec{F}$  on the white ball in a short interval of time  $\Delta t$ . The product of force  $\vec{F}$  times the time interval  $\Delta t$  is called impulse  $\vec{I}$ .

$$\vec{I} = \vec{F} \Delta t$$

Equation 1: Impulse

When the white ball loses the contact with the stick, it acquires a velocity  $\vec{v}$ . Thus, it is correct to say that it acquires an amount of movement  $\vec{Q}$ .

The amount of movement  $\vec{Q}$  is defined as the product of the velocity  $\vec{v}$  acquired by the mass of the ball, as shown in Equation 2.

$$\vec{Q} = m\vec{v}$$

Equation 2: Amount of movement

With Equation 1, it is possible to see that impulse is given by  $\vec{I} = \vec{F} \Delta t$ . The force  $\vec{F}$  will cause an acceleration  $\vec{a}$  to the white ball, making its velocity change from an initial value  $\vec{v}_1$  to  $\vec{v}_2$ , as shown in Educare [2012].

The force  $\vec{F}$  is computed by the Newton's Second Law:

$$\vec{F} = m\vec{a}$$

Equation 3: Force

After applying the shot to the white ball, considering that the player intends to directly reach another ball, it will traverse the table to get in contact with the target ball. The direction angle resulting from both balls after a collision will vary with the angle at which the white ball hit the target ball.

According to Murta (2012), at the time of collision, the time interval is so short that the impulse of external forces is negligible.

The conservation of the amount of movement  $\vec{Q}$ , also known as Linear Momentum, implies that initial  $\vec{Q}$  is equal to final  $\vec{Q}$ .

Fialho [1984] says that the coefficient of restitution in a frontal and one-dimensional collision of two objects (in this case, the billiard balls) is the ratio between the relative velocity of separation between the balls (after the collision) and the relative velocity of approach between them (before collision).

Fialho (1984) explains that, in practice, the value of the coefficient of restitution determines the type of collision that happens. If it is equal to 1.0, we will have a perfectly elastic collision (the final kinetic energy of the system will be equal to the initial kinetic energy). If it is between zero and 1.0 it will feature a partially elastic collision (the one that usually occurs). If the coefficient is zero, the collision is perfectly inelastic and the bodies remain stuck to each other after the shock (special situation).

In this billiard game, it was considered  $e \cong 1$  (perfectly elastic collision).

Tavares (2012) considers a system where there is a ball 2 that moves with velocity  $\vec{v}_{2i}$  towards another ball 1 which is at rest. Both balls have the same mass  $m$  and radius  $r$ .

Given two parallel lines that cross the center of ball 1 and ball 2, the distance between these two parallel lines is called the impact parameter  $b$ .

Murta (2012) shows that immediately after the collision between two billiard balls, the direction of the velocity of each ball make an angle of  $90^\circ$  between them if the projectile-ball velocity vector is tangent to the target ball.

As shown in Figure 1, the red ball with initial velocity  $\vec{v}_{1i}$  reaches the blue ball. The velocity vector of the red ball is tangent to the vector of the blue ball that is in rest. The collision results in a final velocity  $\vec{v}_{1f}$  with direction  $(90^\circ - \theta)$  to the red ball and a final velocity  $\vec{v}_{2f}$  with direction  $\theta$  to the blue ball.

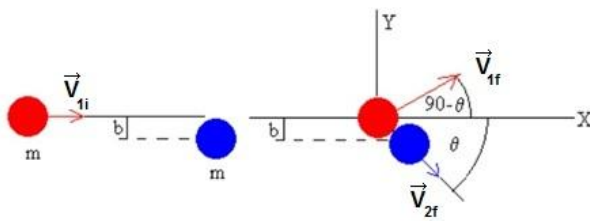


Figure 1: Collision between the balls.

(Source: <http://www3.iesam-pa.edu.br/ojs/index.php/computacao/article/viewFile/582/434>)

### 3. Billiard Game for Teaching Physics

The goal is to make the player, in this case the student of Physics, notice, and learn about the Physical principles involved during the gameplay, understanding the actions and reactions of his plays during the game session.

The game rules are simple:

- It is a billiard game with 16 balls, seven striped, seven plain, a punishment ball, the 8 ball (although this is also be plain, it is not considered an ordinary ball), and the white ball.
- If any player, when making the play, hit the 8 ball before any other, the player will suffer a penalty.
- The penalty is to give the option to the opponent to place the white ball freely on the table, once, before making his move.
- If a player pockets the 8 ball before he has pocketed all his balls, the player loses the game.

As the game consists in a Learning Object, it will be presented information about the force of the shot, the shot angle and the direction of the white ball before the shot. After the shot, the current speed of the white ball is shown in real time.

#### 3.1. Implementation Issues

The game was developed in the XNA, which is based in the programming language C#. Figure 2 shows the high level class diagram of the game.

##### Class Program

The application runs through the class Program, responsible for implementing the Main method, that only instantiates an object of the class Game and call its Run() method, responsible for maintaining the application in the game loop.

##### Class Game

This is the main class of the game in XNA. It is the one who loads and unloads all elements of the game as well as treats the picture on the screen and the logic behind the animations.

This class has attributes that will be used for various methods of its own class and implements some methods such as to draw objects, control the white ball, check the end of the play, apply Physics, detect collision, among others.

##### Class Bola

The class Bola is responsible for the attributes and methods relating to the balls, including the collision of two balls and the impact, calculating the resulting angle and velocity of these balls. It also deals with the calculation of the direction and angle of the balls according to the position of the bat at the time of collision with the white ball.

##### Class Mesa

The class Mesa has the private attributes and methods of the object Mesa, including the detection and

treatment of the collision of one ball with the table or pocket.

### 3.2. Game flow

The game runs in an infinite loop until the player press the "Esc". Figure 3 illustrates the game flow.

After loading the necessary resources through the Initialize() and LoadContent(), the Update() and Draw() methods are called at any time: while the first is responsible for performing all the logical part of the game, the second is responsible for presenting the images of the game on the screen in real time.

Once the player presses "Esc", the game unloads the resources in the UnloadContent() function and gets out of the application through the Exit() method.

### 4. Achievements

The game has a simple interface with the player (Figure 4).

Just below the billiard table, as shown in Figure 5, on the left the user may find the parameter information of the initial move: the shot angle and initial velocity of the white ball. On the right are displayed the speed of the white ball at the moment before the collision with a target ball, and the speed of both balls, shortly after the collision.

Further down, there are two buttons: Teoria and Controles.

If the student wants to see the game controls, just click the button Controles and a new window will open displaying them (Figure 5).

The student has the option to view the theoretical content of Physics present in this game, clicking the Teoria button, and another window is opened as shown in Figure 6.

The game also has sounds to bring a greater sense of realism to the game. All of this is important so that the game become attractive to the student.

When making a play, some information about physical actions that occurred in the game may appear, in the form of a question mark. As shown in Figure 7.

Clicking on the question mark, an explanation of the Physical action occurred is presented, as shown in Figure 8.

### 5. Conclusion

The goal of this work is to develop a way of learning based on a billiard game. The focus is the Physics teaching through the plays made during the session.

The student can improve his playing because it is possible to predict the actions based on physic calculations of the ball path and the strength used.

The Microsoft XNA Framework offers an ambient with the main functions needed to run the application. Besides, the use of C# makes the interaction of the game elements easier because the objects are used with its own attributes. The objects of the real game like the ball, the table and the stick control are better featured.

The big challenge was to guarantee the correct reaction of the collision of the balls. To make it simple, the plays are always aimed to the center of the white ball.

The sounds are played in real time to give the sensation of reality – the play, the collisions, the ball in the pocket and the ambience.

The player receive all the information he may need, like the angle of his aiming, the strength he is going to use, the speed and the path of the white ball, before his play. He also receive the information of the keys he can use.

Through in this game the student can visualize some physics concepts, like impulse, conservation of the amount of movement, kinetic energy, law of reflection and elastic collision.

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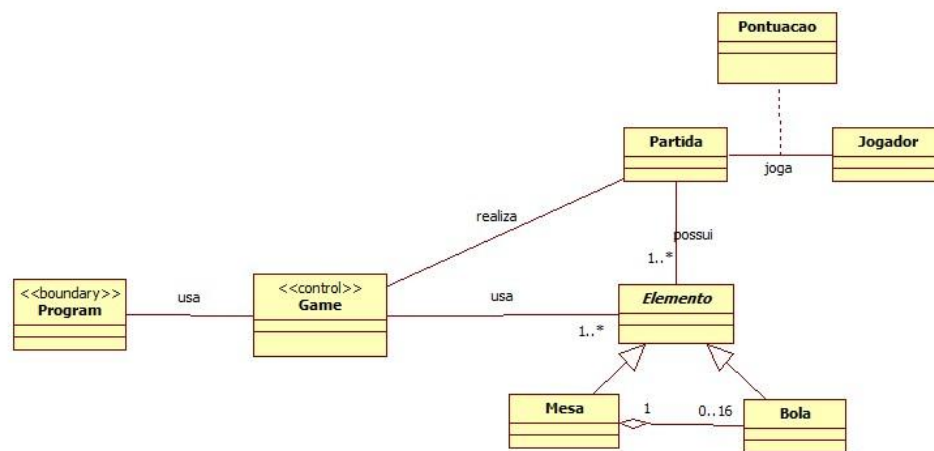


Figure 2: Class Diagram of the game

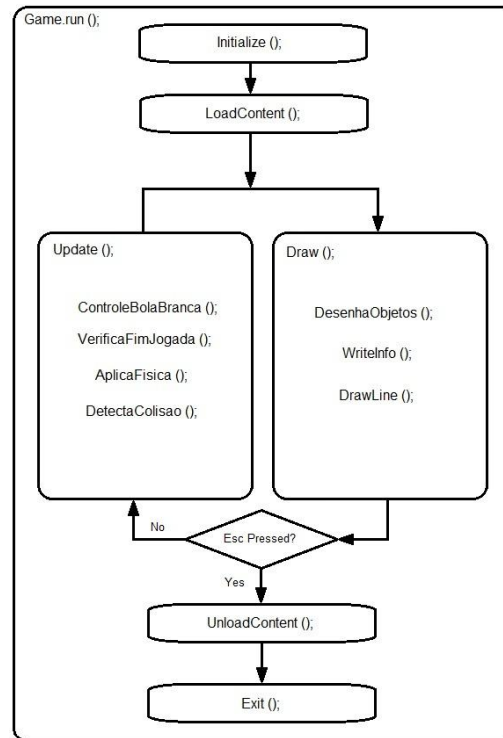


Figure 3: Game flow



Figure 4: Game main interface

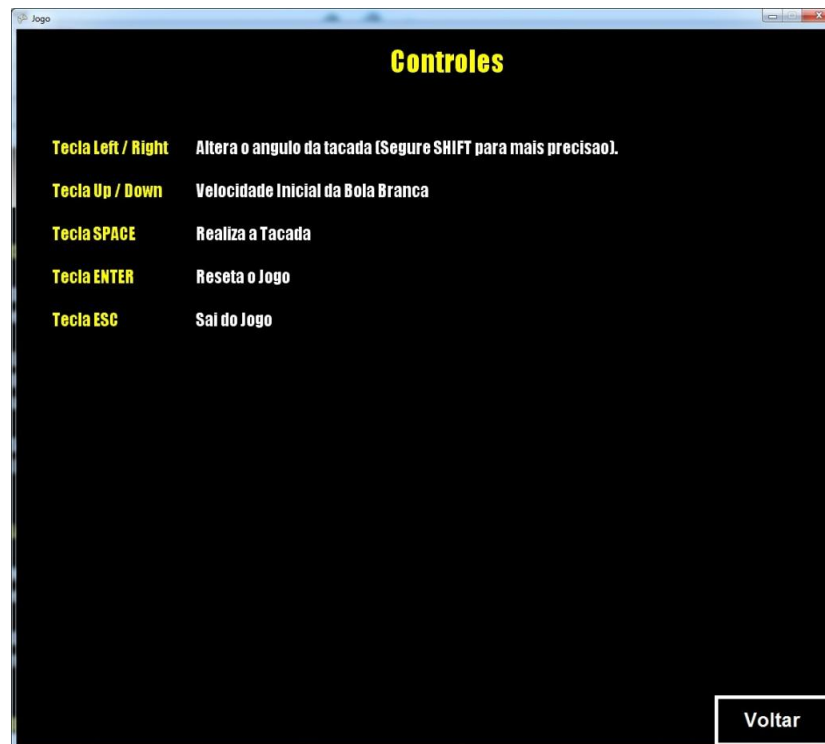


Figura 5: Game controls window

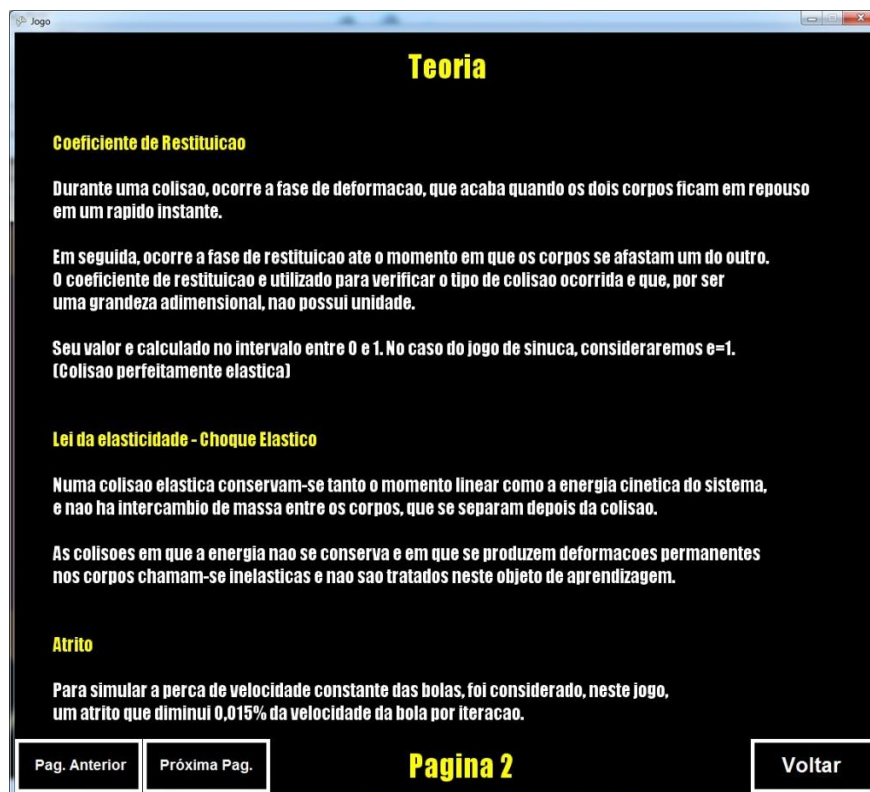


Figure 6: Theoretical content window



Figure7: Image of a play



Figure 8: Information presented in real time