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# Physics Learning in Primary and Secondary Schools with Computer Games—An Example — Angry Birds

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## Abstract

In this paper, we discuss how we can make physics lessons more interesting with the use of information and communications technology (ICT). We explain why physics teachers need to be ICT competent and which ICT tools teachers can use to improve their lessons. Nowadays, many learners spend their free time playing computer games that use basic physics laws for game mechanics. One of our goals was to find out which computer games would be appropriate for learning physics and how to include those games in the learning process. We also show an example how to teach physics using the computer game *Angry Birds*, where we take into account primary and secondary school curriculum. Finally, we analyze how teaching physics with computer games affect students and what are the benefits and weaknesses using this method. In addition, we conduct a survey to gain insight on the opinion of physics teachers about the appropriateness of the computer game *Angry Birds* for teaching physics in elementary and high school. Surprisingly, the teachers find the game more appropriate for the teaching of physics in elementary school, despite of the fact that there are physics themes mostly from high school physics included in the game.

**Keywords:** ICT, Angry Birds, computer games, physics, teaching, e-learning, curriculum

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## 1. Introduction

The fast penetration of information and communication technology (ICT) into our lives and society is causing how, when, and where we work and study. School-aged children nowadays

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spend their free time immersed in a media-rich, ubiquitous, always-connected world where most of the time they usually play computer games. For two decades, scientists were trying to figure out why are computer games so motivating and why children spend so much time playing them [1]. The results of research were three features: challenge, fantasy, and curiosity. The same three features are also very important aspects in learning. Challenge helps us to stay motivated to achieve our goal, fantasy helps us to better imagine how things should work, and curiosity drives us to figure out things that we did not know.

Educators around the world in the last 50 years try to incorporate ICT and computers into the education system. Four threads have been identified [2]. The first thread, computer-assisted instruction (CAI) and lately intelligent tutoring systems (ITS), has promised a new way of how learners would learn but never gained much attention. Second thread, computer science and computer programming, is gaining momentum lately as few countries are bringing them as obligatory subjects in school curriculum. The third thread is cognitive development and problem solving skills, which are getting much of attention as problem solving is one of the key competencies for 21st century citizen. The fourth thread is Internet use for gathering information and as a tool for improving problem solving skills. Perhaps the greatest potential for ICT in education is the improvement of traditional teaching with the inclusion of different tools in the classrooms.

The next generation of jobs will be characterized by increased technology use, extensive problem solving, and complex communication [3]. These are the skills that go beyond typical reading, writing, and arithmetic of years past. It is not only what students need to learn that is shifting but also how and when they learn. Students of today are growing up with laptops, tablets, cell phones, and video call, and they expect to use this technology in their daily interactions [4].

One area of significant promise in this regard is a movement toward the use of educational computer games as learning tools in schools [5]. We will tackle this area in subsequent sections.

This chapter is structured as follows, we first categorize computer and educational games, and then we introduce the computer game *Angry Birds* and describe how *Angry Birds* can be used in physics curriculum. Next we explain which computer programs and how to use them with *Angry Birds* in the classroom. We conclude this chapter with the survey on how teachers would use *Angry Birds* in classrooms.

## 2. Computer and educational games

For the purposes of this paper, we will define a game as a system in which players engage in artificial conflict, defined by rules, that results in quantifiable outcome [6]. A definition of digital game requires a game system to incorporate technology. Simulations, augmented reality, and traditional computer games meet the requirement. However, purely virtual worlds, such as Second Life, would not be games because there is no quantifiable outcome [5].

The different types of computer games are as follows [7]:

- **Card games**—Its computerized version of typical card games and games where game mechanics involves playing with cards where graphics can make card more alive in the virtual world. Examples *Poker*, *Solitaire*, and *Black Jack*.
- **Board Games**—These are virtual presentation of classic board games like *Chess*, *Monopoly*, and *Backgammon*.
- **Puzzles**—These are games that are mostly evolved around problems. In these games, the player must figure out a solution for the given problem using different in-game tools to solve an enigma. Good examples are *Tetris*, *Mastermind*, *Brain Age*, *Ilomilo*.
- **Maze**—The basic mechanics of this is evolved by problem of navigation, where a player's main objective is to get out of the maze. Examples are *Pack Man*, *Doom*, *Wolfenstein 3D*.
- **Fighting**—Fighting games involve characters who usually fight hand-to-hand in one-on-one combat situation. Examples are *Street Fighter* and *Avengers* [7].
- **Action**—These types of games involve control of a character who proceeds through story and shoots to objects and enemies. Nowadays, we can also refer to this type of games as first-person shooter (FPS) games. These are very popular and can be played online against other players. Examples are *Counter-Strike*, *Call of Duty*, *Unreal Tournament*, and *America's Army*.
- **Adventure**—Adventure games are similar to action games, but they evolve more around the story and mystery behind it. Players are often placed in historical environment where they try to solve a mystery. Examples are *Zork: Grand Inquisitor*, *Quest for Glory IV*, *Grim Fandango*, and *Gone Home*.
- **Role playing**—In role-playing games, players can choose between different types of character. Play style depends from what type of character you have chosen. Characters may differ from gender, abilities, races, specializations, profession, and other specifics that games have to offer. When a character is chosen, you can adventure in the virtual world where you can go on a quest where you deal with different problems and adversaries. During quests, you upgrade your character in agility, strength or magic. This type of game is very popular nowadays, and it is mostly played online. This type of game is called massively multiplayer online role-playing game (MMORPG). Examples are *Diablo*, *Titan Quest*, *World of Warcraft*, and *Skyrim*.
- **Strategy**—strategy games emphasize on involving a strategy to defeat your opponent. In this game, players need to resolve a problem of resources, economy, defense, and attack. Most known strategy games are *Age of Empires*, *Warcraft*, *Civilization*, *Europa Universalis*, *Total War*, and *Stronghold*.
- **Sports**—These games are mostly a virtual presentation of real-life sports, where the player picks a team or individual and compete in sport discipline. Most known are *FIFA*, *NHL*, and *NBA*, among others.

- **Simulation**—There are two types of simulation games, training and management. At training simulation game, designers try to simulate a real-world environment, where you can practice. Good examples of training simulation games are games *Wheels of Steels*, *Flight Simulator*, and *Ship Simulator*. Management simulation games are about managing community and economy. Good examples of these games are *Tycoon* series, *The Sims*, and *SimCity*.

These games are mostly a product of big entertainment companies, which can provide enough funding for game designers and programmers to develop new games and to sustain old ones up to date. If we can compare these games with didactic games, we can surely get to the conclusion that designers of nondidactical games put more effort to make games fun and graphically appealing and, in this case, also more playable. Another factor is freedom of game designers at nondidactical computer games. They do not need to evolve game around lessons that should be learned in certain stage of game, but they have more freedom at designing environment details and effects. Also, they put more focus on playability of the game rather than learning a certain lesson. That gives nondidactical computer games advantage in popularity.

Research in the United States has shown that majority of children and adolescents nowadays are playing computer games for at least 1 hour per day [6]. This indicates that computer games take a great part not only in children's but also in adolescents' everyday life. Many parents are worried that playing games too much could lead to addiction, violence, and depression of their children, but they mostly overreact because they fail to see the positive effects of playing computer games and are mostly misled by media. Computer games changed dramatically, and they became much more complex, diverse, and social in nature, which means that they offer much more to players than they did in a previous decade. Let us check what we can gain and what the benefits at playing computer games are. Research has shown that computer games can improve cognitive brain functions. Numerous studies have shown that computer games can help at faster and more accurate attention allocation, higher spatial resolution in visual processing, and enhanced mental rotation abilities. It is also interesting that spatial skills can be trained relatively quickly and skills like this can be easily transferred in real-life usage. Preliminary research has also demonstrated that these cognitive advantages manifest in measurable changes in neural processing and efficiency, which means that players of computer games can filter irrelevant information much faster than nonplayers. However, we must say that these benefits do not apply to all genres of games but mostly to games where 3D environment is included.

Great benefit can be also gained with problem solving skills, which is dependent on game complexity. It seems that nowadays children have evolved around the aspect of problem solving. We rarely see someone reading a manual, but they mostly learn by trial and error, which can also be related to computer games where game designers often offer very little instructions how to solve a problem. A final cognitive benefit from playing computer games is enhanced creativity. Another benefit from playing video games also shows up in the motivation of players. It seems that many computer games are stimulating just enough

frustration that players stay highly motivated to solve the problem and take great pleasure succeeding. It seems that challenge in games provides enough motivation and fun for players to play the game, and that makes a positive effect on them in a way to attain better motivation and persistence, which can also lead to better marks at school if the same can be applied to learning. Another benefit from playing computer games is on the emotional state of a player. Gaming may be among the most efficient and effective means by which children and youth generate positive feelings. Puzzle games like for instance *Angry Birds*, which has minimal interfaces, short-term commitments, and high-degree of accessibility can improve player moods, promote relaxation, and ward off anxiety, which can also result in higher self-esteem and better grades in school. If playing a game can make a person happier, then this is a great factor that we can gain from playing games and may result in various positive effects such better inspiration and connectivity. Computer games stimulate not only positive emotions but also negative ones, which may not be as grim as it sounds. By stimulating just enough negative emotions such anger, anxiety, frustration, and sadness, we are able to take control of those feelings and learn how to react on them, which can also lead to better adaptive behavior. Playing computer games also improves our social skills. We already said that games changed a lot from last decade, and they also changed in social prospective. Majority of players nowadays play computer games with their friends and rarely alone, which also indicates that they must obtain certain social skills to be able to communicate with friends. Nowadays, some online games provide players with lots of social possibilities where they chat and even send emoticons to each other. Game designers also enforce collaboration between them, so players have to work together to defeat greater adversaries, and that mostly requires good communication skills and coordination [8]. Due to all of benefits that we can gain from computer games, why not use them as a teaching material.

Computer games that were designed for learning are called educational games [2]. What makes games “educational” are specific characteristics [1]. Educational games should also have appropriate methods for learning contents, which depends on nature of contents. For example, we must distinguish between learning of knowledge, processes, procedures, and casual principles. Each of those requires different learning methods that depend on content’s complexity. Methods that are used for learning also affect game structure and game mechanics. Finally, what every educational game should have is a feedback system that provides players with information of learning success. We described key characteristics of educational games, where we found out that game structure and game mechanics depend on game content and methods of learning [5]. On the other hand, we need to ask ourselves why children prefer playing classic computer games than educational computer games. The key element is that educational games are not primarily designed for fun only, and major software companies do not develop educational games. Those companies have expert knowledge in computer graphics and game designs, but they have discovered that educational games are not commercially successful and revenue is too small for them. So to get good learning results in computer games, we should either design and develop better educational games or find those computer games that are popular and could be used for educational purposes.

At this point, we must also mention game-based learning, which is defined as “an innovative learning approach derived from the use of computer games that possess educational value or different kinds of software applications that use games for learning and education purposes such as learning support, teaching enhancement, assessment and evaluation of learners” [9].

Some computer games are using actual physics as their game mechanics, and children are very eager to spend hours playing them. So why don't we use those as a teaching tools for physics? One of those games that are using actual physics as their game mechanics is the very popular computer game *Angry Birds* but is not specifically made for teaching.

### 3. Computer games and physics

Nowadays, a lot of pupils at the end of their secondary school are discouraged to go to study physics. If we would ask them, why is that so, we would get a common answer that physics is boring, hard to understand, and not interesting. This response from pupils mainly results from physics teacher's old-fashioned methods of teaching. Most of teachers are using main-frame (or traditional) method, teaching by telling, which seems to be less effective and boring for students than inquiry-oriented teaching [1]. A great help for this method is the use of information and communications technology (ICT). To use all these, the physics teacher needs to be e-competent [10]. It means that the physics teacher should be able to successfully use ICT as tool for teaching. The use of ICT gives us access to a lot of information, and it is also essential for the support and development of functional skills required in life. It is also a great motivational factor because many of the pupils have highly developed skills of using ICT, and it allows pupils to maintain their concentration longer [10,11]. With the use of ICT, we can effectively collect, display, and introduce data to pupils, and it is also a great tool to deepen knowledge. Teacher priority should not be only to teach physics and deliver information to pupils but also to teach them how to find this information (collecting information) and define which information are correct and useful for them (selecting information).

Learners are not always aware that the game that they are playing is using basic physics laws for game mechanics. Consequently, we could use these games as a didactical tool to teach them physics and make physics lessons more interesting for them. All we need is a computer and a software that measures and shows analyzed data from computer game. There is a variety of games that can be used for experiment. A well-known game and still very popular is the game *Super Mario Bros*. It can be used with problem-based approach for calculating basic kinematics and studying different problems within Mario world [12]. A very interesting game for learning physics is also *Scorched 3D*. In this game, a player must set the power, angle, direction of a projectile to hit another tank while considering the wind affecting the projectile course. In this game, we can learn the physics of projectile motion and introduce it clearly to the students [13]. Sometimes you have to fail in game to figure out how to complete the mission. A game that is made on this concept is called *Angry Birds* [14], where you use different birds as projectiles to destroy green pigs. We can use this game to teach various concepts in physics. Next, we present an example of how to provide physics teaching with *Angry Birds*.

## 4. Angry Birds

*Angry Birds* games are a product of a Finnish company called Rovio entertainment. The first game was released in year 2009 for Apple's iOS Android, Symbian, and Windows Phone operating systems. Since then, Rovio entertainment upgraded the game that can also be used on PCs and game consoles. Its addictive gameplay, comical design style, and low price has made the game very popular in almost any age-group. Its popularity also encouraged the company to make new sequels with different themes. From the first game *Angry Birds* to latest sequel *Angry Birds Transformers*, eight more sequels are listed, with different themes and game mechanics [14].

### 4.1. Game insight

The basic story of *Angry Birds* is about evil green pigs called "bad piggies," which are constantly stealing unwatched eggs from birds, desiring to cook and eat them. The pigs are under the command of King Pig, who commands his army of pigs to construct as many structures as possible to keep the birds from reaching him. The main protagonists of the game are the birds, which are trying to get their eggs back before the evil pigs can eat them. Red (Bird) is the main character of the *Angry Birds* series and also the leader of the flock. He does not have any special abilities and has appeared in every version except *Angry Birds Stella*. There are also Chuck the yellow bird, who has the ability to drastically accelerate; Jay, Jack, and Jim called "The Blues" with the ability to separate in three same-sized birds; Bomb the black bird, who has the ability to explode; and Matilda the white bird, whose ability is to drop one egg on the pigs. There is also Hal the boomerang, who can be seen as the green bird in many sequels and has the ability is to fly back like a boomerang. Bubbles the orange bird is also one of the flock crew members. He has the ability is to drastically expand and push all obstacles away. The newest member of the flock is Stella. She has different abilities like trapping objects into bubbles, speeding up when screen is tapped, and rebounding of walls [15].

### 4.2. Game mechanics and materials

In the game, a slingshot is used to shoot birds in a way to eliminate all green pigs that may be protected with different materials, which can be destroyed easier with a specific bird's ability. The game is also designed wherein you gain difficulty in every level, and sometimes it requires you to do the same level many times before you finish it. With difficulty scaling with every level, it also motivates and drags you to play the game. When you successfully complete a level, you can also keep track of the score that you achieved, which is measured by the stars that you gain. The final mark of how you performed in a specific level is dependent on how many objects you destroyed and how many birds you used to eliminate green pigs [14]. We already mentioned that we have different materials (Figure 1) in the game, and we know that different materials have different properties, and it is also the same in *Angry Birds*. The basic materials in the game are stone, wood, and glass [15].

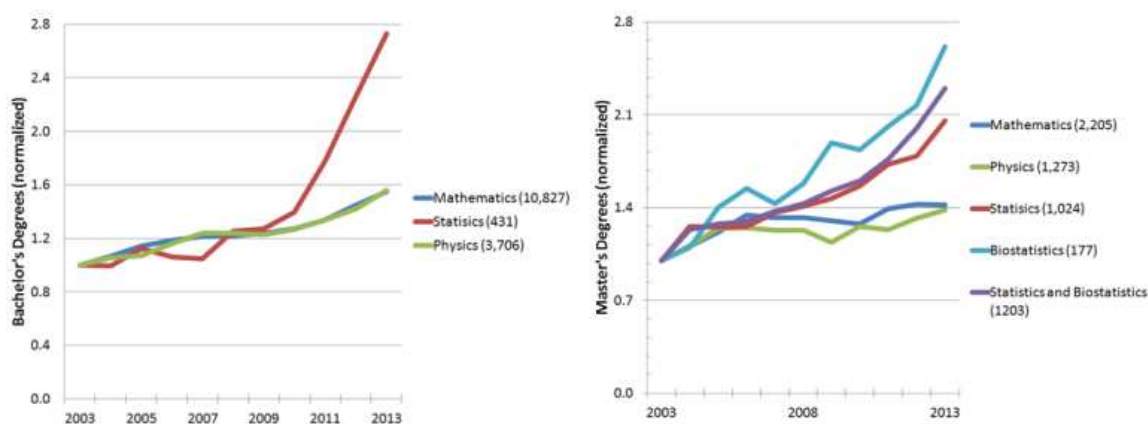


**Figure 1.** *Angry Birds* gameplay showing an example how to shoot a bird to destroy pigs hiding inside the walls. Stone, wood, and glass are the basics materials. How hard are they to destroy is not always dependent on the material but also on the shape of the material. Small square-shaped blocks are mostly harder to destroy than long square-shaped blocks.

## 5. Why is physics not popular?

Physics is not very popular among students, and consequently, the educators all over the world are facing the same problem in stimulating students to study physics (Figure 2). Most of the countries have shortage of physics teachers and scientists. The question is why is physics so unpopular among the students? The common beliefs that we encounter about physics are that physics is not an easy subject, it requires a high degree of dedication, and it is mostly meant for intelligent people who are sometimes socially discriminated, and because of that, they are discouraged to study physics. The most common replies that we get about physics when we ask people who finished high school or are still studying are as follows: “physics is boring,” “physics is difficult,” “physics is for boys,” and “physics is strange and only crazy people are doing it” [16]. Why are most responses so negative? What is the problem? It seems that pupils in elementary school show big interest in physics when you ask them about topics that can be found in physics curricula like, for example, electricity, magnetism, force, universe, and others. However, it seems that interests are greatly lowered in high school when they are actually faced with a higher degree of knowledge about them, which includes the use of mathematic at higher degree and this causes students difficulties at understanding physics and also discourage them [17].

It seems that teaching methods and math involvement at a higher degree of education are the origin why students get lack of interest in physics. The question is What can we change to motivate students and to show them that physics is one of the essential science disciplines that not only brings great results at developing technologies but also gives us understanding how nature is working? Also, physics teachers often do not enjoy teaching physics. The main reason may be hidden behind physics curricula, which give really small flexibility at lesson distribution during the year, and the teacher really does not have time to improve their lessons because they have to deal with the lesson schedule for the year. There seems to be two crucial problems.



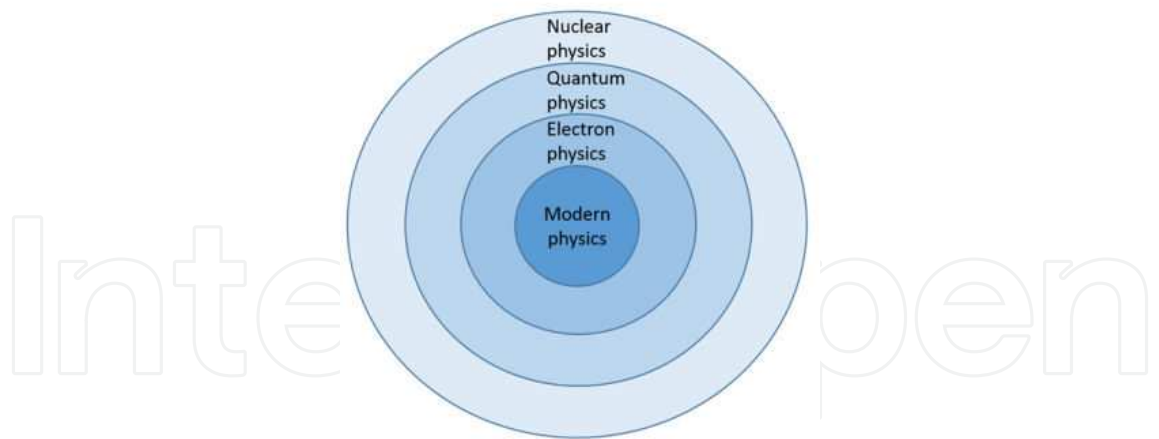
**Figure 2.** We can see from the ASA Community research that physics is far behind other science disciplines in master's degree. On the left chart, we can see that physics and mathematics bachelors who finished the degree are rising very slow compared to statistics. On the right chart, the number of students who finished master's degree is far behind other disciplines like biostatistics and statistics [18].

One of them is a problem on how to introduce knowledge to students in that they will find it interesting, which is basically the problem of teaching methods. The other problem is physics curricula. It seems that physics curricula in many countries is not flexible enough for teachers and, as a result, is unfriendly to students. The solution to this problem would be to redesign physics curricula in a way to give the teacher more flexibility and hereby also relieve teachers from pressure so they could actually enjoy teaching physics and give full dedication to more attractive lessons. A great solution for teaching methods could be to include physics in other subjects such as computer science, where students could solve physics problem with the use of ICT. Games are also a great solution, where students could learn parts of physics simply by playing games and gain necessary knowledge. One of appropriate computer games from which students could learn physics is *Angry Birds*. We present which themes from physics curricula could be appropriate to teach concepts of physics.

## 6. Physics curricula and *Angry Birds*

All over the world in every school, teachers must follow a teaching plan called curriculum. In every curriculum, there are mandatory themes that consist of subthemes that are building the whole teaching process in certain order. How this process consists may differ from country to country. We may also say that the system of learning physics is concentric (Figure 3). Each physics curriculum is constructed from basic themes. The most important difference between curricula in different countries is in subthemes and their order. In physics, cores of concentric circles are the main themes, which are mechanics, matter, waves and optics, thermal physics, electricity and magnetism, modern physics, and astronomy [19].

The basic themes of physics curriculum are defined, so we studied which of those we may find in the computer game *Angry Birds* and which of them we can analyze.



**Figure 3.** Example of concentric circle in physics. Outer layers may differ in number of subthemes and variety of sub-themes titles, but the core stays the same.

**7. Mechanics**

**7.1. Forces and Newton’s law, collision, and explosion**

We know that when we launch a bird from the slingshot, the only force that is affecting the bird is the force of gravity  $\vec{F}_g$ . The air resistance force is in the game excluded. We also know that when the bird will collide with a wooden wall, it will be affected with the force of wall  $\vec{F}_w$  that is resisting bird’s movement in the opposite direction of its movement (Figure 4). Children can monitor and watch examples of collisions and explain how forces are working on the observed object. We already mentioned that black bird has an ability to explode from which we could observe effects of explosion to teach children the basic physics behind it.



**Figure 4.** We can see that the force of gravity  $\vec{F}_g$  is the only force that affects the bird in the flight. Also, we can predict that when the bird hits the wall, it will slow down because the force of the wall is resisting the bird’s motion.

## 7.2. Friction and motion

With the help of *Angry Birds*, we can also explain friction. After finishing the flight, the bird is touching and then rolling on the ground with some speed in the direction of the vector of velocity  $\vec{v}$ . The bird is slowing down because of friction  $\vec{F}_f$ , which is working on the bird in opposite direction and causing the bird eventually to stop (Figure 5). With this example, we could explain how friction is working on a (rolling) bird.



**Figure 5.** We can see that force friction is working in the opposite direction of the bird, causing the bird to slow down.

## 7.3. Circular motion and gravity

We mentioned before that Rovio entertainment released many sequels. One of much known sequel is called *Angry Birds Space* (Figure 6), where the game environment is in space and the gravity of objects affects the bird's flight. In designing this sequel, Rovio Entertainment worked with NASA, which helped at programming gravity effects and also tested them in actual space. In the game, we could learn the effects of gravity. Also, we can learn the basics of circular motion if we launch the bird in the angle where the bird would circle around the small planet, which is affecting the bird with its microgravity.

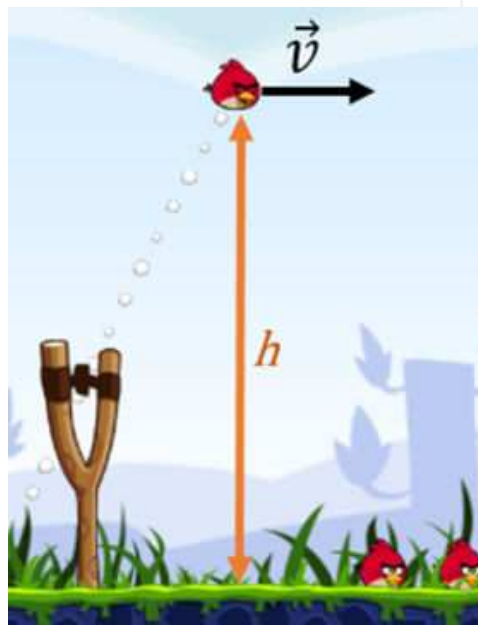


**Figure 6.** We can see that the force of gravity is pointing in the center of the small planet's mass, therefore also affecting the path of the bird's movement, which would circle for longer time if the force of gravity would be smaller or the velocity of the bird would be higher.

### 7.4. Work, energy, and power

We know that birds are moving with certain velocity  $\vec{v}$  when we launch them. We also know that they change height when they are launched (Figure 7). From that aspect, we can also explain the change of kinetic and potential energy, where potential energy is changing according to change of height:

$$E_p = mgh, \quad (1)$$



**Figure 7.** If we know height and velocity, we can determine potential and kinetic energy; therefore, we can also know how much work and power the birds need when we shoot them.

where  $E_p$  is the potential energy,  $m$  is the mass of bird,  $g$  is the gravitational acceleration, and  $h$  is the height where the bird is located in correspondence to the ground. We could also explain the change of kinetic energy as follows:

$$E_k = \frac{1}{2}mv^2, \quad (2)$$

where  $E_k$  is the kinetic energy of bird and  $v$  is its velocity. We can also determine work as a result of energy change as follows:

$$W = \Delta E, \quad (3)$$

where  $W$  is work and  $\Delta E$  is change of energy. From that, we can also determine average power as follows:

$$P_{avg} = \frac{\Delta W}{\Delta t}, \quad (4)$$

where  $P_{avg}$  is the average power, and  $\Delta W$  is the change of work in time interval  $\Delta t$  [20].

We can see that with the computer game *Angry Birds*, we can cover and explain most of the mechanics. Other themes are not so well covered, but we can still find something. For example, we can explain buoyancy.

### 7.5. Buoyancy

We can explain that buoyancy is upward force  $\vec{F}_b$  exerted by a fluid that opposes the weight of an immersed object, which is shown by gravity force  $\vec{F}_g$ . We can also see that one piggy is floating, which is the result of comparison of the average density of piggy to density of liquid in which piggy is located. For floating of the piggy, its density has to be smaller (Figure 8).



**Figure 8.** Here we can see an example where force buoyancy is working in the opposite direction as gravity force, causing the material and the pigs to float to the surface [21].

We showed some examples where we could use the computer game *Angry Birds* as a didactical tool for main topics in physics curriculum. However, we did not talk about experimental work and measurement, which is the main topic in following chapter.

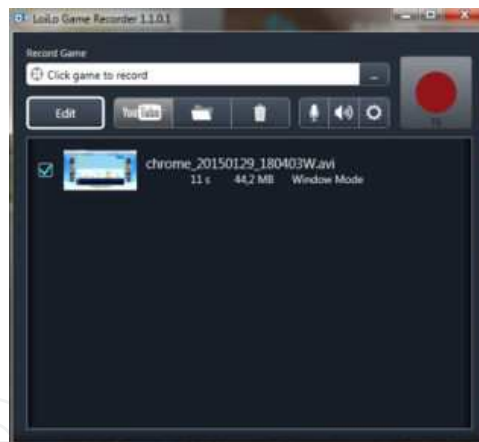
## 8. Teaching with *Angry Birds*

We described some topics where the computer game *Angry Birds* could be appropriate for teaching physics. It contains many mandatory topics of physics curriculum, and it can either be used as a motivational tool, where children could get more comfortable with physics while using ICT or it can be used as an experiment to show children simulation of actual physics. From the experiment, we could define exercises where children could get basic knowledge

about physics and calculus behind it. In this chapter, we show an example of how we can teach the physics of projectile motion using the computer game *Angry Birds*. Before we can explain the physics of *Angry Birds*, we have to make footage of *Angry Birds* gameplay, and after that, we can analyze data in that footage. For that, we need some additional programs appropriate for classroom usage, for which we present some examples.

### 8.1. LioLo Game Recorder

The recommended software for making gameplay footage is a program called LoiLo Game Recorder. You can download it for free from their website [22] and install the program on your computer. LoiLo Game Recorder is a program that enables us to record game sessions. It also supports Motion-JPEG file format that provides with the best balance between file size and image quality. For our purpose, we recorded full-HD videos, and file size is still manageable. When you downloaded and installed the program, simply start the program and the game in which you want to make a recording. Before you start to play, press F6 on keyboard and program will start recording (Figure 9). After you finish playing, press key F6 again and the program will stop recording and save the footage in your PC's video directory. Now you can use the footage for analysis. To minimize the measurement errors at analysis of gameplay, the footage must be smooth and without delays [22]. We will do our analysis in program called Tracker.

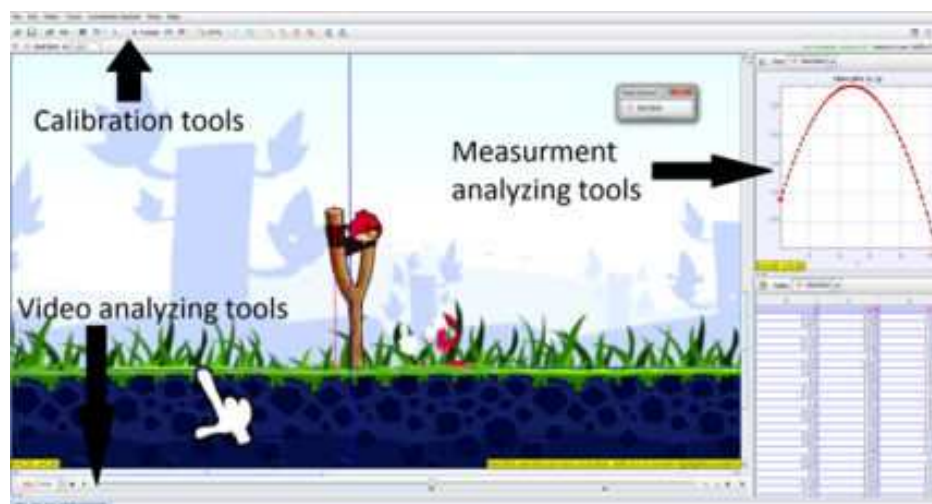


**Figure 9.** This is the LoiLo Game Recorder's user interface where we can see options available in program. We can also see an example of the footage that we made in *Angry Birds*.

### 8.2. Tracker

Tracker is a free video analysis and modeling tool built on the open source physics (OSP) Java framework. It is designed to be used in physics education and can be easily run from USB drive. Requirements for using Tracker are small, and it only requires that you have installed Java 1.6 or higher. It has a variety of tools to help user to analyze the data from recording where we can read what happened with physical quantity on the graphs (Figure 10). To analyze data from recording, we simply start the program Tracker in which we can open video that we have

made with the program Loilo and start the measurements with different tools [23]. Before we can acquire the measurements for discussing physics problem, we need to set starting point to place our bird in space. We do that with calibration tool where we set the coordinate system in the foot of slingshot, which will be our starting point. We also need our measuring unit, which in our case will be the slingshot size. When we determined starting point and basic measuring unit, we use tracking tool to track bird's movement in the footage. When tracking is finished, we see all measurements in the graphs, which we can analyze with measurement analyzing tool. The program Tracker also has a video-analyzing tool where we can depart video frame by frame. For final results, we use measurement-analyzing tools where the data are displayed in different graphs.



**Figure 10.** The program has many tools to offer; the most essential of them are the calibration tool, which we can find at the top; the measurement analyzing tools at the right; and the video analyzing tool at the bottom of program interface.

### 8.3. Physics of Angry Birds

When we have analyzed the data with the program Tracker, we can start talking about physics in games. Projectile motion is a case of motion which we can describe it as motion in two dimensions: vertical and horizontal. In this particular case, we can neglect air resistance because the game was not designed to include air resistance in projectile motion. We know that when we shot a bird slingshot, its initial speed ( $\vec{v}_0$ ) is

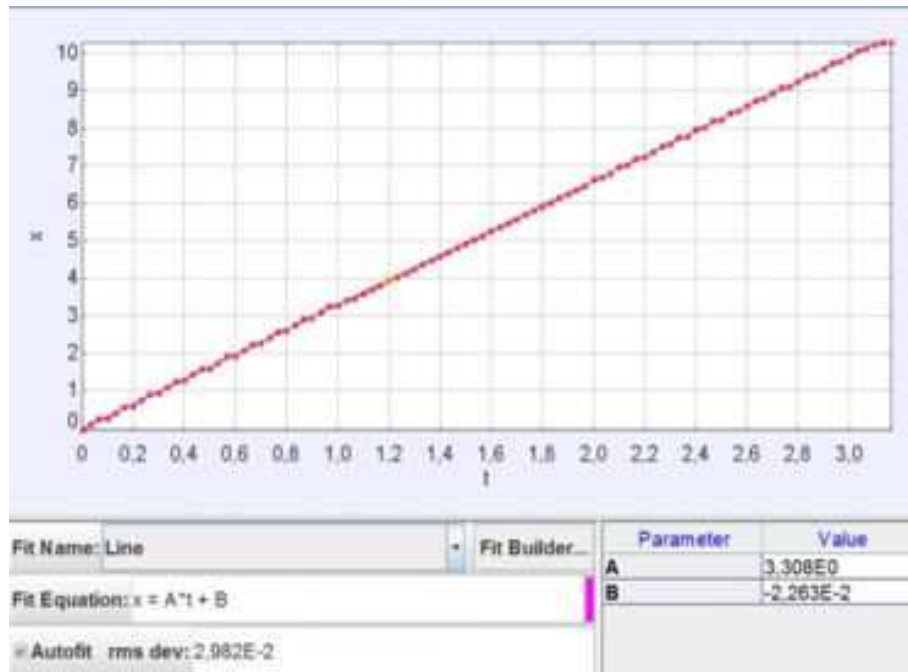
$$\vec{v}_0 = (v_{0x}, v_{0y}), \quad (5)$$

where  $v_{0x}$  is the size of the horizontal component of initial velocity and  $v_{0y}$  is the size of the vertical component of initial velocity [20]. The only force that is affecting the bird during the flight is gravitational force. That is why acceleration of bird is equal to the gravitational acceleration.

We also know that the horizontal component of velocity is not changing in size because acceleration only got vertical component. That is why we can define the movement of bird in time  $t$  :

$$x_{finished} = (v_{0x} \cos \theta)t + x_{starting} , \quad (6)$$

where  $x_{finished}$  is the location where bird has finished movement in time  $t$  in his horizontal path and  $x_{starting}$  is the initial location from where bird has started moving in horizontal path.  $\theta$  is the angle by which we shot the bird from slingshot [19]. As a result, we get Figure 11, which shows us that the body was moving in horizontal direction with constant velocity  $v_{0x}$  equal to 3.31 U/s [24].



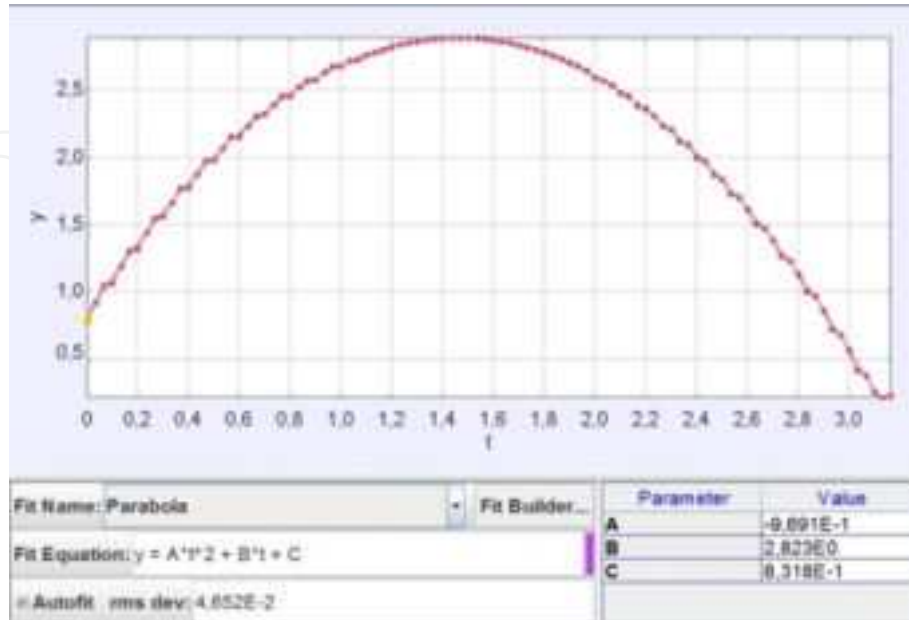
**Figure 11.** From the measurement, we can read that the horizontal component of velocity (A) is 3.31 U/s, and we can see that dependency position from time is linear.

For motion in vertical direction, we know that acceleration is constant. That is why we can define motion in vertical direction as

$$y_{highest} = (v_{0y} \sin \theta)t - \frac{1}{2}gt^2 + y_{starting} , \quad (7)$$

where  $y_{starting}$  is the starting height from which the birds was shot in vertical direction from angle  $\theta$  and  $y_{highest}$  is the maximum height that the birds will reach in at time  $t$ . We also see that acceleration is equal to gravitational acceleration  $g$  if our game is happening on Earth. From

the measurement, we see that vertical motion fits to quadric equation (Figure 12), which also shows us that acceleration in vertical direction is constant and is equal to  $-1.9 \text{ U/s}^2$  [25].



**Figure 12.** From Equation (7), we can see that acceleration (A) in vertical direction is  $a/2$ , which gives us a result acceleration equal to  $1.9 \text{ U/s}^2$ . From the measurement, we can also read the vertical component of velocity (B), which is  $2.8 \text{ U/s}$ , and height (C), which is  $0.8 \text{ U}$ .

From the result, we wanted to determine what was the size of our basic unit. We measured acceleration in vertical direction as  $1.9 \text{ U/s}^2$ . We placed our experiment on Earth so acceleration should be equal to gravitational acceleration, which is  $9.8 \text{ m/s}^2$  [24,25]. From that, we can calculate what was the size of our basic unit, and we get the result that our slingshot was  $5.1 \text{ m}$  high because the size of the slingshot was set as our basic unit. When we get our basic unit, we can calculate our velocity in vertical and horizontal directions so that we simply multiply our measured values with  $5.1 \text{ m}$ , and as result, we get that  $v_{0y}$  is  $14.2 \text{ m/s}$  and  $v_{0x}$  is  $16.7 \text{ m/s}$ . From this point, we can calculate initial velocity as follows:

$$v_0 = \sqrt{v_{0x}^2 + v_{0y}^2}, \quad (8)$$

and we get that  $v_0$  is  $21.9 \text{ m/s}$ . From these measurements, we can also calculate our starting height  $h_{\text{starting}}$ , which is  $4.2 \text{ m}$ . When we obtain the starting height, we can also calculate the maximum height as follows:

$$h = \frac{v_{0y}^2}{2g} + h_{\text{starting}}. \quad (9)$$

We get that the maximum height  $h$  is 14.5 m. It is also interesting to know from which angle did we shoot the bird:

$$\theta = \tan^{-1}\left(\frac{v_{0y}}{v_{0x}}\right) \quad (10)$$

As a result, we get  $\theta = 40.4^\circ$ . When we all needed information, we can also calculate the range  $d$  of the bird's flight using the following equation:

$$d = \frac{v_0}{g} \sqrt{v_0^2 + 2gh_{\text{starting}}} \quad (11)$$

where we get range corresponding to value 52.8 m. We get a similar result when the range is 10.5 U, which is 53.0 m. We see that the range that we calculated is not the same as the range that we measured. We can explain that as an error in measurements.

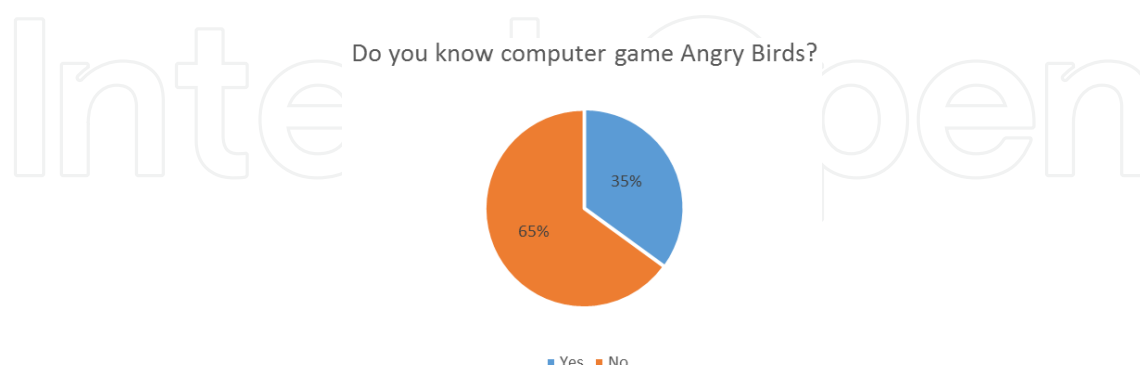
#### 8.4. Use of example in classroom

We have seen how we can analyze physics with the red angry bird, which does not have any special abilities. This type of analysis and understanding would be more appropriate for pupils in secondary school, in which pupils could use this particular experiment to determine the actual size of birds and the actual size of the slingshot, like we have shown in our example. We can also use experiment for teamwork, where we could divide pupils in two groups. The first group would have to explain the physics of vertical motion, and the second group would have to explain the physics of horizontal motion. At the end of the experiment, both explanations can be merged, and the physics of projectile motion can be explained. Our example can be also used in primary school, where we would have to lower the difficulty of tasks for pupils. We could teach them how to use the programs LoiLo and Tracker for simple analysis not only in *Angry Birds* but also in any other experiment footage. With this experiment, they can get familiar with graphs and errors in measurement. We also know that there is much more physics that can be explained with the use of *Angry Birds* for physics lessons. For additional work, students could explore the initial acceleration and midair acceleration of the yellow angry bird when we use his special ability. It would be also interesting to check the physics background of the blue angry bird, where students could check what is happening with momentum when he splits into three same-sized birds and if the mass of all three birds is the same. We already mentioned materials that show up in the game. For additional project work, students could analyze how different angry birds affect the same material.

### 9. Research

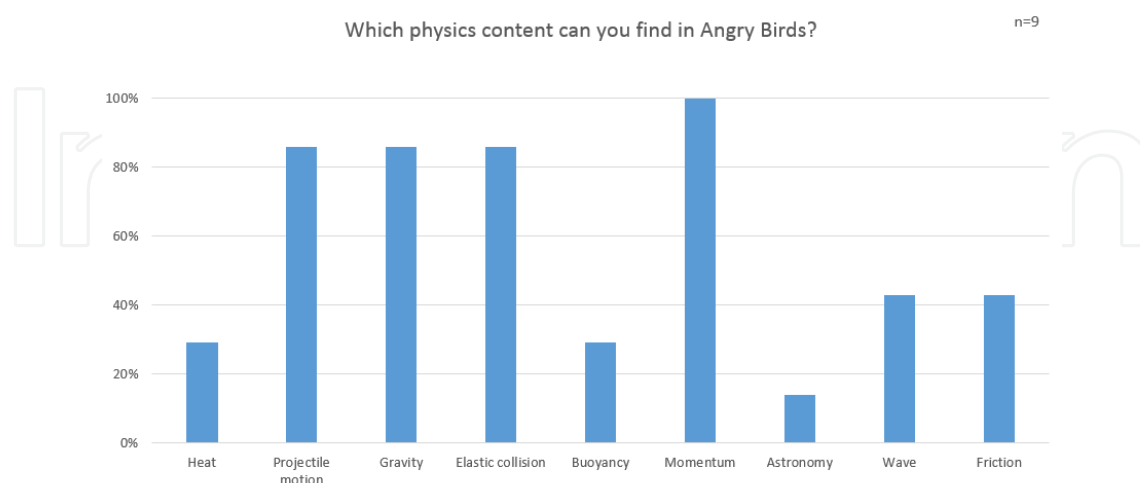
We showed an example of an experiment that could be used in the class. However, the question is if teachers would even use *Angry Birds* as a didactical tool. That is why we started research where we wanted to see teachers' responses on the proposal of teaching with *Angry Birds*. Our

targeted group of teachers was mostly middle-aged teachers (age 36 years and older). We know that the use of ICT is in average a bigger problem in older teachers rather than new young teachers. That is why the middle-aged group is much more interesting. On the question if they know the computer game *Angry Birds*, 35% of the teachers answered yes (Figure 13), which is actually impressive according to age-group that was questioned.



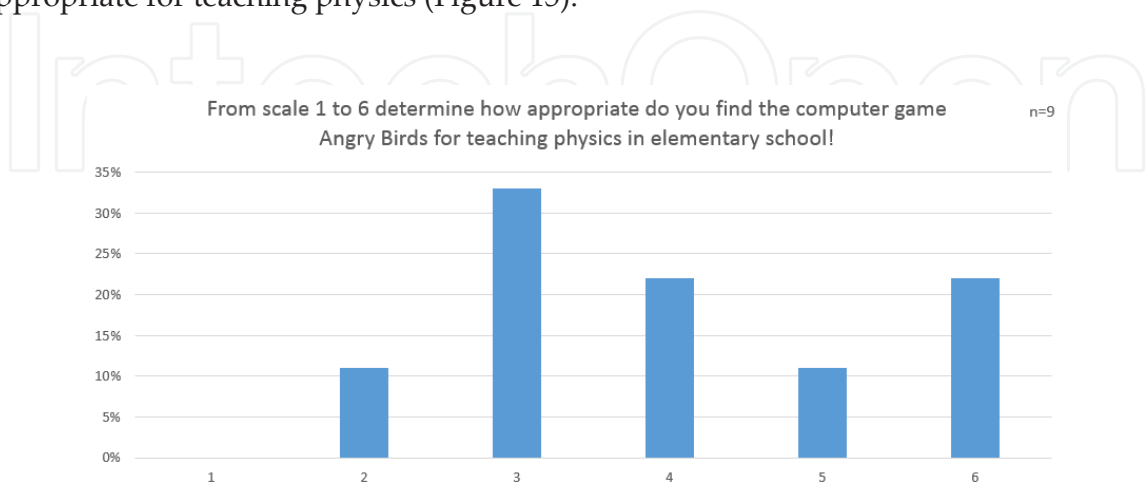
**Figure 13.** Chart where we can see how many teachers know the computer game *Angry Birds*.

With this, we have determined our group of teachers who actually know the game. Later on, we wanted to know how well they know the game. Hence, we set some common questions about the effects of the birds in the game and which of the physical content they see in the game is also included in physics curriculum. As a result, we learned that teachers who played *Angry Birds* know the game pretty well; 83% knew the effects of the birds in the game. The more interesting part comes when they had to determine the physical contents they found in the game, and the result was amazing. We found that physics teachers have noticed 9 different physics themes (Figure 14) in the computer game *Angry Birds*, which shows us that game really is suitable for physics class.



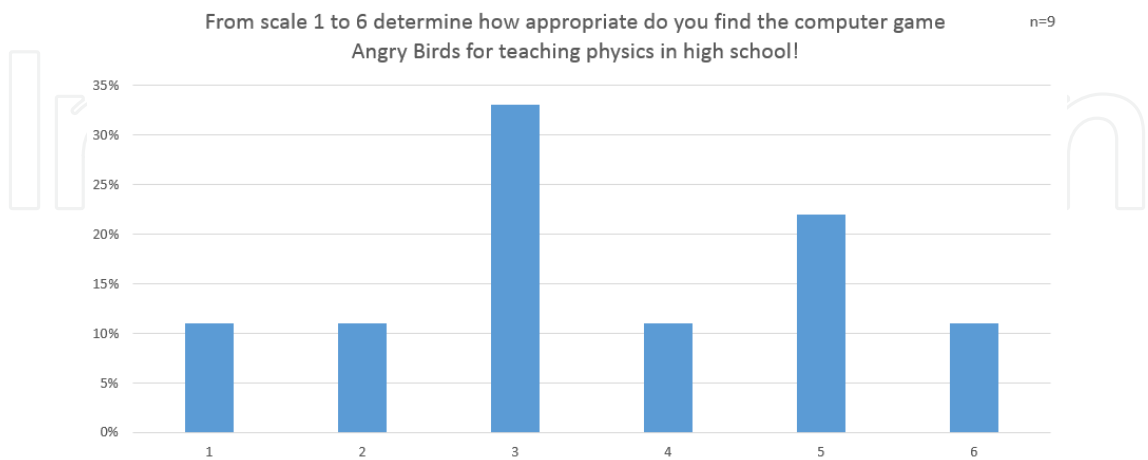
**Figure 14.** In the chart, we can see what teachers have found in the game *Angry Birds*: heat, projectile motion, gravity, elastic collision, buoyancy, momentum, astronomy, wave, and friction. The vertical axis shows the percentage of teachers who found certain physics content in the game. The horizontal axis shows the different physics contents.

We figured out that teachers can definitely see that game contains content for teaching physics. We also wanted to gain insight what teachers think about the suitability of the game in teaching physics in elementary and high school. Thus, we asked them how appropriate do they find the computer game *Angry Birds* for teaching physics in elementary school. None of teachers evaluated the computer game *Angry Birds* as inappropriate, and more than half of them find it appropriate for teaching physics (Figure 15).



**Figure 15.** On the vertical axis, there is percentage of teachers who evaluated suitability for elementary school from 1 to 6, where 1 indicates completely inappropriate and 6 indicates perfectly suitable for teaching physics in elementary school, which could be found on the horizontal axis. We see that more than half of teachers found the computer game *Angry Birds* for teaching in elementary school as appropriate; 22% of them found it also perfectly suitable for teaching physics in elementary school.

We also asked them how they would evaluate the suitability of the computer game *Angry Birds* for lessons in physics in high school (Figure 16). We got results that more than half of teachers find it appropriate for teaching physics in high school.



**Figure 16.** On the y axis, there is a percentage of teachers who evaluated suitability for high school from 1 to 6, where 1 indicates completely inappropriate and 6 indicates perfectly suitable for teaching physics in elementary school, which could be found on the x axis; 11% of them found it also perfectly suitable for teaching physics in high school.

In our survey, we also asked if the computer game *Angry Birds* is appropriate as a motivational tool in lessons in elementary and high school. As a result, 78% of the teachers find the computer game *Angry Birds* as a great motivational tool for both elementary and high school. The most impressive result was when we asked them if they would use the game for teaching physics. All of the teachers that know the computer game *Angry Birds* would use it for teaching physics.

### 9.1. Methodology

For our research, we used free online survey tool 1ka.si [26]. The tool offers many options to design an electronic survey. We took into account all basic rules of making survey where we limited the number of questions per page on 5 and separated the different topics of question in separate pages so the survey itself was not too harsh for respondents. In the survey, we also made a break point where we eliminated teachers who do not know the computer game *Angry Birds*. If they answered “no” on a question where we asked them if they know the computer game *Angry Birds*, the survey was finished; if they answered “yes,” they could continue with the survey. We sent our survey through e-mail. The results that we introduced were analyzed in Excel table, where we merged our results in charts appropriate for the type of data that we got. In the research, we included 41 physics teachers who finished their study between the year 2005 and 2015 at our faculty and students of educational physics study. We got the response of 26 persons, 9 of them were familiar with the game *Angry Birds*.

## 10. Conclusion

In this article, we determined that the use of ICT in learning is a skill that every teacher should acquire during his education. If we look in the present and, even more important, if we look in the future, ICT will be a main tool for learning. We also learn what the difference is between EG and fun CG. We found out that some computer games like *Angry Birds* could be more appropriate material for teaching because of its motivational fun factor. In educational game, designers mostly forget about it because their main point is focused on teaching, and game mechanics are obstructed by learning processes, in which most children forget that learning new things can also be fun. We became familiar with two new programs LoiLo Game Recorder and Tracker, which can be used for analysis. We also show an example of how we could use *Angry Birds* for teaching projectile motion where we explain the physics of *Angry Birds*. At the end, we also check the applicability of *Angry Birds* and how it can be used for further courses. We also conducted one research where we found out that most of the teachers think that *Angry Birds* is appropriate for teaching physics in high school and elementary school.

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