BJRS

BRAZILIAN JOURNAL
OF
RADIATION SCIENCES
10-03A (2022) 01-17

PLATAGAM: a video game structured as a didactical material for divulgation of some of the benefits of the Gamma Radiation produced in the Cobalt-60 Multipurpose Irradiator at IPEN's facilities

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ABSTRACT

This paper aimed at the conception and implementation of a platform video game designed to make known some of the benefits of the use of Gamma Radiation produced in the Cobalt-60 Multipurpose Irradiator, built with Brazilian technology at IPEN's facilities. Unity 3D game engine and some other software for image editing were used. Four missions await the player, illustrating the following benefits of gamma radiation irradiation: on foods and beverages to retard deterioration and interrupt microorganisms proliferation; on tilapias, which skins are used in bandages for burns; on surgical materials as a sterilization procedure; and, finally, on museum items, for eradication of plagues on the collection. The authors hope that the offering of this didactic material will aid some effective Science Learning, mainly about pacific uses of Nuclear Technology.

Keywords: **nuclear technology benefits, educative video games, didactic materials**

ISSN: 2319-0612
DOI: https://doi.org/10.15392/2319-0612.2022.1851
Submitted: 2022-01-27
Accepted: 2022-09-29

1. INTRODUCTION

In Brazil, during the last two decades, public policies have increased the process of digital inclusion for public schools and at distance education. Allegedly, a great portion of the XXI century new generation was born to a digital global context, where technology and widespread access to information are granted. Furthermore, the social distance demanded by COVID-19 pandemics implied the closing of most schools, thus emphasizing the importance of distance learning.

Brazilian official documents such as “Parâmetros Curriculares Nacionais” endorse classroom technologies use [1]. Available Information and Communication Digital Technologies (ICDT) merged with the pedagogical project of schools pose a challenge and have been the object of ample debate nowadays. All of this may generate a much more stimulating learning environment for this generation.

The use of ICDT is recommended for scientific divulgation in schools of all levels. Therefore, this work presents the conception and implementation of a video game designed to show playfully some nuclear technologies applications, as a didactic material for a meaningful learning.

This work is a part of a major project, dealing with IPEN’s technical visitation by means of Virtual Reality. As a member of the Comissão Nacional de Energia Nuclear (CNEN), IPEN conducts scientific and technological research, deals with teaching, executes services, and provides nuclear products for Brazilian communities.

IPEN's Radiation Technology Center (CETER) has developed and implemented the Compact Type Cobalt-60 Multipurpose Irradiator, featuring all-new Brazilian technology. This irradiator uses gamma (γ) radiation to irradiate various products and follows the same trend as commercially available compact irradiators, with the advantage of continuous product processing.

The research made at IPEN and similar institutions, even at the Information Age, are ample involved in some prejudices and misconceptions. Due to the very nature of the necessary activities, ample access to installations and facilities are not granted, especially to children. Nuclear accidents also contribute to this picture, making it difficult to spread the social advantages and benefits of nuclear technologies.

Given this context, this work aims to present the platform video game deployed to emphasize the Cobalt-60 Multipurpose Irradiator and its applications: the PLATAGAM. It addresses a modest contribution to the teaching and scientific divulgation of some of IPEN's activities in a playful way, to students of various age groups and on an interdisciplinary view, once the theme involves several areas of knowledge.

2. MATERIALS AND METHODS

2.1. Educational Practices and Games

ICDT merged with the pedagogical projects of schools poses quite a challenge for educators. It is hoped that the introduction of all these new technologies generates a more attractive learning environment to this century's new student generation. Known as New Millennium Learners or NetGeneration, this generation was born and raised immersed in the use of technology [2]. Thus, video games kindled educators' interest and some of them even propose their use in an educational environment as a didactic material towards a more dynamic and attractive learning, capable of increasing the students interests in more scientific and academic themes.

The meaningful learning aimed in all this process demands students engagement not only with their syllabus but also with their knowledge schemes updating, comparisons, similarities, identifications and integrations and then to realize the coherence in the final result. In this context, it is extremely important the presence of the teacher as a mediator to create and lead the complex educational practice [3].

All the complexity of the variables resulting from the educational practice can be gathered and labeled as a didactic unit. This didactic unit is a pedagogical sequence of structured activities for the accomplishment of a certain educational objective. These units have the virtue of maintaining the unitary character, while being instruments that allow the inclusion of the three phases of all reflexive intervention: planning, application and evaluation [3].

The activities or tasks of the didactic unit concentrate most of the educational variables and are driven by the choice of curriculum materials. This work provides the educators some curriculum material so that they can create within their own space-time context their own didactic sequence.

Curriculum materials or curriculum development materials are all those instruments that provide the educator with references and criteria for decision-making, both in planning (as in direct intervention in the teaching / learning process) and in its evaluation [3]. The video game proposed in this paper is an example of a curriculum material, a tool to help teachers respond to the concrete problems that the different phases of the planning, execution and evaluation processes present to them.

Digital games designed for a purpose other than just fun, but intended to instruct, educate, entertain the player with some serious theme or concept are called serious games or applied games [4]. These games have been used in various areas such as defense, health, business, tourism, psychology, politics, religion and education [5].

Digital Game Based Learning (DGBL) represents a category of serious games, particularly the ones focused on learning. DGBL is a pedagogical methodology focused on the conception, development, use and application of games in education and training [6]. Games are contexts structured with the potential to provide student (player) motivation and involvement in order to provide personalized learning experiences, promoting long term memory, that is, favoring meaningful learning [7].

Games feature well-defined rules, with clear objectives and challenges, reinforce decision-making skills, and motivate the player to win. Facing damage or punishment pose challenges. Digital games are interactive and motivating, carrying emotions, pleasures, unique challenges for plot unfolding [8].

This paper presents a platform DGBL game. The name "platform game" is given to a genre of electronic games in which the player controls an avatar that runs and jumps between platforms and obstacles, dealing with damages and collecting objects. The genre had its appearance in the 80's, and one of the best known examples is “Super Mario Bros.” It’s considered a classic, released in 1985, and it was one of the best selling games in the history of video games [9].

The video game developed and implemented in this work aims to disseminate the applications of Cobalt-60 Multipurpose Irradiator. To this end, students need to be briefly informed about the radiation involved in order to gain a qualitative understanding of what happens inside such an irradiator.

2.2. Cobalt-60 Multipurpose Irradiator

IPEN's Radiation Technology Center (CETER) has developed and implemented the Compact Type Cobalt-60 Multipurpose Irradiator, featuring all-new Brazilian technology. It consists of a small size continuous run and multipurpose industrial gamma (γ) irradiator. It can be used as a facility for manufactures, contract service, and also for supporting the local scientific community [10].

Radiation processing technology has been used worldwide for water treatment, medicine, tissue engineering, disinfestations and disinfection of books and documents, among others. The irradiation is used to preserve, modify or improve the characteristics of the product or material. Products of various shapes and constitutions, when exposed to a specially designed environment, can be treated through exposure to ionizing radiation (gamma rays, electron beams and X-rays) [10, 11].

The process is carried out, on a fixed time interval, by placing the product near a radiation source. A fraction of the radiation energy that reaches the product is absorbed by the product, depending on the exposure time and its mass and composition. Although the source emits radiation, the product that is irradiated does not become radioactive [12].

The Compact Type Cobalt-60 Multipurpose Irradiator uses gamma (γ) radiation, which comes from the nucleus of the cobalt atom. Gamma radiation is emitted by excited nuclei in their transition to lower-lying nuclear levels, and its decay scheme is illustrated in Figure 1. Cobalt-60 is widely used as a gamma-ray source for industrial use, mainly because of its non-solubility in water and its easy production method [12, 13].

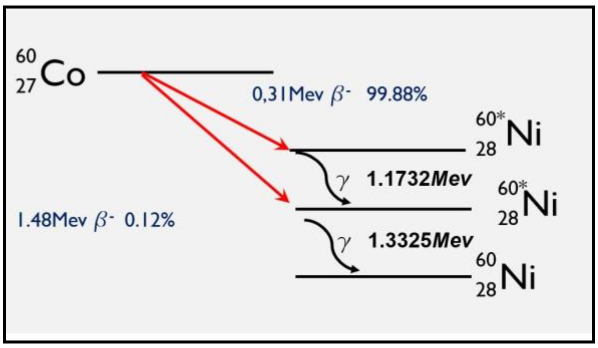

Figure 1 : *Cobalt-60 is unstable and decays to Nickel-60.*
Source : [14]

Cobalt-60 sources are produced from Cobalt-59 metallic pellets made out of 99.98% pure cobalt, generally encapsulated in Zircaloy. The capsules are activated in a nuclear power reactor, where a Cobalt-59 atom absorbs a neutron and is converted into a Cobalt-60 atom, with a specific activity of 4 TBq/g (120 Ci/g) [10, 12].

The Cobalt-60 Multipurpose Irradiator follows the same trend as commercially available compact irradiators, with the advantage of continuous product processing. The irradiator covers 76m² of floor area, and its technology consists of a continuous tote box transport system composed of a single concrete vault, where the products are transported in and out through a revolving door integrated into the shield [15].

The licensed capacity load for this irradiator is 37 PBq (1 MCi), with a water pool liner manufactured in stainless steel. The Cobalt-60 radioactive sources are stored in the pool where the water has several desirable characteristics as a shielding material [16].

After the irradiator is turned on, the Cobalt-60 plates rise to the surface and the radiation reaches the desired level. The concrete door for entry and exit of products is unique and revolving, allowing a reduction in the size of the irradiation room and the absence of internal mazes, reducing the installation cost. The main characteristics of Cobalt-60 Multipurpose Irradiator are presented in Table 1 [15].

Table 1: Characteristics of Cobalt-60 Multipurpose Irradiator.

Total capacity	37 PBq (1 MCi)
Initial activity of operation	3.7 PBq (100kCi)
Pool	7.0 m deep and 2.7 m diameter
Concrete doors	1 slider for installation and maintenance of the installation and 1 swivel for entry and exit of products in the irradiation chamber
Concrete wall	1.8m thick (density = 2.35 g / cm^3);
Font Geometry	2 rectangular source racks with capacity for 600 Co 60 rod;
Font Dimensions	1 rack 1.4 m long x 2.1 m high and 1 rack 0.7 m long x 2.1 m high
Irradiation System	product overlapping source, continuous, double stacking of boxes, each box level moving in the same direction (horizontal) but in opposite directions;
Camera capacity	16 boxes, approximately 4.32 m^3;
Irradiation Doses	greater than 1 kGy in one irradiation cycle;
Irradiation time	variable according to the product to be irradiated;
Volume per box	270 liters / 0.27 m^3
Maximum weight per box	300 kg
Maximum annual capacity	variable, according to the density of the product.
Carton Size	50 cm x 60 cm x 90 cm;

The IPEN Cobalt-60 Multipurpose Irradiator, as its name implies, is used for several purposes, in this work only four were addressed:

1. **Irradiation of cultural collections**

The multipurpose irradiator uses radiation technology in the treatment, recovery and conservation of furniture, clothing, manuscript and printed documents, books, paintings and other objects that have historical and cultural value. Gamma rays penetrate the material and reach the cells of insects and microorganisms, destroying DNA thus causing cell death, promoting the disinfestation and sanitation of cultural collections [17].

IPEN has performed the work of decontaminating and conserving cultural collections free of charge when dealing with government institutions. One of the advantages of the irradiation technique is that the collection is processed without being removed from the boxes used as transport packaging, avoiding possible accidents in the movement. Another advantage is that there is no contamination of the works with any kind of poison, which by traditional methods, may cause health damage [18].

2. **Food and Beverage irradiation**

The application of radiation in food is a totally safe technique that allows microbiological control without alterations of taste, color and nutritional value. The technique increases the shelf life of dried foods and the shelf life of seeds, vegetables, tubers and fruits. It is also used to control the spread of insects on flowers and leaves, and to slow down the deterioration of different types of meat. In food irradiation, relatively small doses can eliminate insect proliferation, medium doses can block the proliferation of microorganisms, and larger doses can even sterilize food, in this case for preservation for very long periods without refrigeration or for feeding people with reduced immunity. For each desired benefit, the minimum and maximum dosage applicable to the product and the feasibility of application into the irradiator are decided [17].

3. **Irradiation of Nile Tilapia Skin**

Nile tilapia (Oreochromis niloticus) belongs to the cichlid family, originates from the East African Nile River basin, and is widespread in tropical and subtropical regions. In northeastern Brazil, particularly in Ceará reservoirs, tilapia fish farming is widespread. The skin of this fish is a noble and high quality product, which has a peculiar resistance [19].

Tilapia skin is used as a gauze in superficial and deep second-degree burn injuries, and in other specialties such as gynecology, otorhinolaryngology, endoscopy and vascular wounds. Like the tilapia skin, human skin, bones, tendons, cartilage, amniotic membrane, briefly, most biological tissues that are used in transplants, bandages and other clinical applications are treated with ionizing radiation to minimize the possibility of rejection and reduce the risk of transferring contagious diseases such as HIV, hepatitis C or cytomegalovirus [20].

4. **Irradiation of surgical materials**

The IPEN Multipurpose Irradiator is also used for sterilization of medical disposable materials and for sterilization of containers used for transport and use of radiopharmaceuticals. As gamma radiation has a high penetration power, the products to be sterilized can be irradiated within their sealed packages. The process is ecological, does not release toxic emissions or wastes and does not affect the environment. Products can be used immediately after sterilization [17].

2.3. The construction of the video game

For the development of this work, some of the techniques and documentation available for building virtual games were employed. The process of creating and completing a game includes the design of the game play, story and style, the creation of art assets and the scripting process [21]. To achieve this goal, the chosen methodology demanded mastering the skills required to use some software packages available in the Internet, such as Autodesk Autocad, image editors like: Irfanveiw, Paint e Pixlr, and Unity Games Engine.

AutoCAD is a computer aided design (CAD) software that architects, engineers and construction professionals rely on to create precise 2D and 3D drawings. It was used to draw and edit the scene. This work employed the free student version. Popular image editors such as Irfanview, Paint and Pixlr were used for manipulating and editing scene images, formatting and background removal.

A game engine is a library of packaged features and tools, conceived to ease the development of a game, in such a way that not everything should be crafted from scratch. Many commercial game engines developed for original game titles released their programming structures for the construction of other games. Among them, one of the most regarded in this market and freely available for small developers, the Unity 3D game engine was the chosen one here.

This game engine allows game and app creations suitable for diverse computer operating systems running various browsers, mobile devices and VR platforms. The access to Unity 3D is free for companies with yearly revenues up to US$ 100,000.00. Besides that, a vast documentation, models, textures, codes and free or paid training modules are available for developers. It is not required to be a programmer to develop a game with Unity, however, it is necessary to understand the structure of the scripts and C# programming language knowledge is recommended [21].

In the development process it was also also important to consider some key concepts of human computer interaction, such as user experience and usability, which in the context of gaming, can be replaced with the terms "player experience" and "playability". Mainly on educational games, these factors must be combined with motivating and meaningful strategies, enabling learning and entertaining [22, 23]

In this aspect, the game was developed focusing on entertainment, fun to beat obstacles, intrinsic rewards and new things to learn. Although there are methods to evaluate the player experience and the playability, at this point of the project this has not yet been applied. The focus was to develop some teaching materials with low cost, however, future works could consider these evaluations to ensure better results.

3. RESULTS AND DISCUSSION

The platform game PLATAGAM is the result of this work and is available on the itch.io website at: https://patriciapaladino.itch.io/platagam.

The process of the game development included a monitored visit to the Cobalt-60 Multipurpose Irradiator, some experiments with the construction of games to better understand the game engine, and several freehand sketches, which were then outlined on a computer, using AUTOCAD. These preliminary steps were essential to develop the game story.

The player needs to complete four missions to win the game, considering each mission features a beneficial application of gamma radiation. When the game starts, the player's avatar is initially in the center of the representation of the Cobalt-60 Multipurpose Irradiator. The player can move left and right using the arrow keys and can also jump using the space key or run using the W key.

The scenario is divided into eight regions: the irradiator, the fruit region, the market, the tilapia region, the pollution region, the industry region, the museum, and the hospital. Figure 2 shows the division of the scenario, where the arrows indicate the movements the avatar must perform in order to accomplish the missions. The avatar must go through the scenarios using the mobile platforms and tile maps.

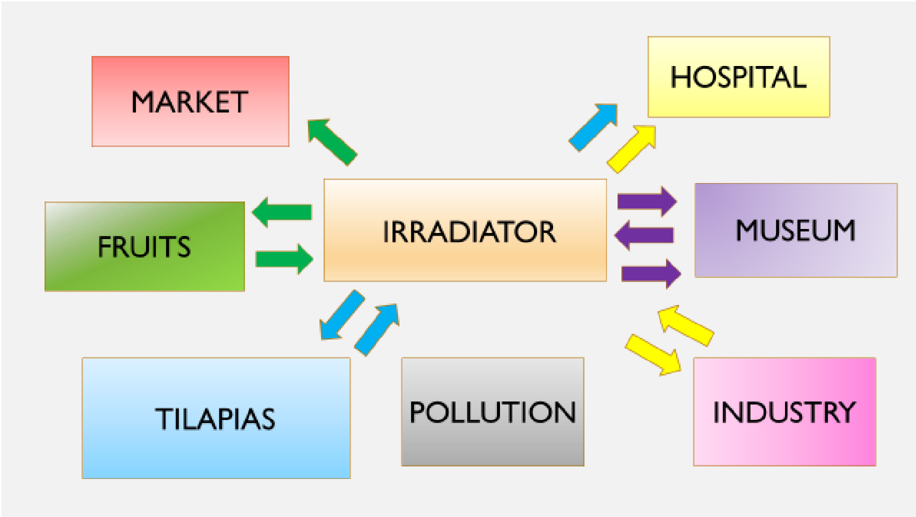

Figure 2 : *Movements in game scene.*

3.1. The plot

The four missions are described above:

1. Collect the apples, take them to the irradiator to radiate and then deliver them to the Market (Fig. 3).

Figure 3 : *The market and food irradiation.*

2. Collect the tilapias, take them to the irradiator and then deliver them to the hospital (Fig. 4).

Figure 4 : *Tilapia collecting.*

3. Go to the museum, collect the insect-infested collections, bring it to the irradiator and return it to the museum (Fig. 5 and 6).

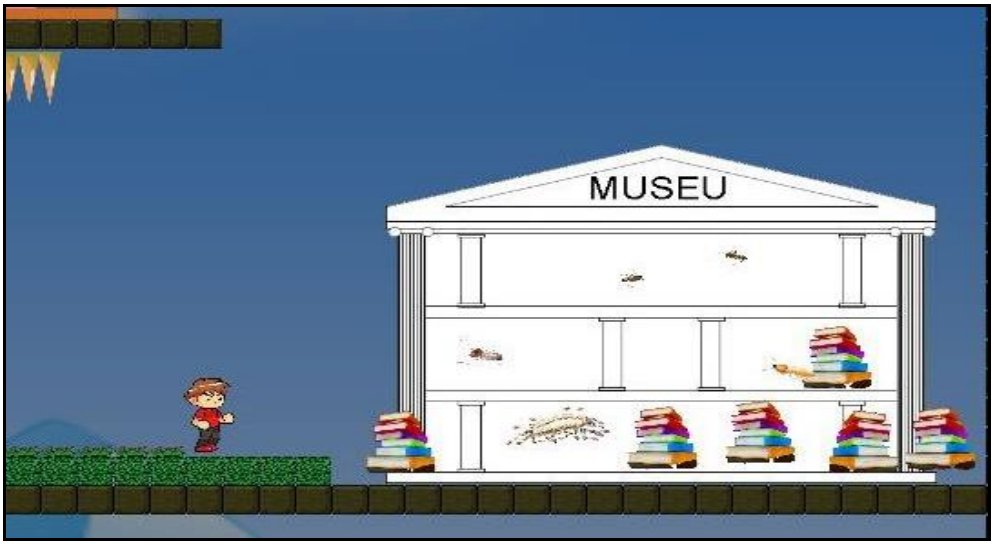

Figure 5 : *The collections on the museum are infested.*

Figure 6 : *The collection was irradiated*

4. Collect the boxes with surgical material in industry, radiate them in the irradiator and then deliver them to the hospital. Figures 7 and 8.

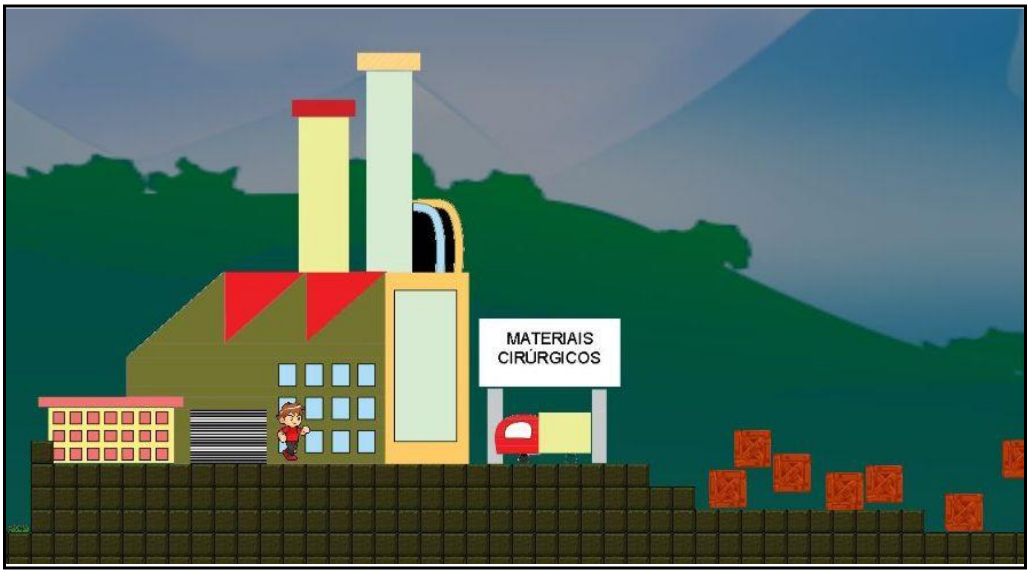

Figure 7 : *The surgical materials industry.*

Figure 8 : *The hospital.*

As each mission is accomplished, something happens in each respective scenario, and the player gets a life. The game ends when all four missions are completed, or life's count reaches zero.

3.2. Damage and Difficulties:

1. The game starts with 3 lives.
2. Thorns cause damage by taking a player's life.
3. If the player falls into the polluted river, he or she loses all lives and game's over.

4. CONCLUSION

The product of this work is the video game PLATAGAM, a curriculum material for spreading the benefits of gamma radiation. Curriculum materials, as methodological variables, are often unduly neglected even though it is curriculum materials that dictate teachers' activity. The existence or not of these tools defines the degree of flexibility and creativity of the teacher when planning the didactic sequence.

The video games are interactive, motivating, generate a series of events arising from the narrative, viz., to collect elements, take them to the irradiator, deliver them in the appropriate places; all these actions depend solely on the player, who by discovering the missions and how to solve them, memorize the good results of gamma radiation applications. Being multisensory, the game's image, sound, music, sound effects and playability with immediate feedback, the game is indeed very attractive. On losing, the player can always try again.

This work essentially was a proof of concept, hopefully showing that it is possible to develop some teaching materials with low cost, since all the software could be used for free.

The difficulties encountered in the making of this final product are those related to the manifold skills required for the construction of the video game such as the rendering of the graphical interface with the game engine domain, the use of C # programming language for game structuring, and the theoretical study of the applications of gamma radiation, involving in site visits and interviews with the professionals involved.

The very realization of this video game shows the possibility of creating digital games in various domains of knowledge and that the learning process can be enjoyable and amusing. Future development of both 2D and 3D games will be continued, and some testing is already underway for the creation of DGBL in Virtual Reality.

ACKNOWLEDGMENT

The authors are grateful for the financial support provided by Instituto de Pesquisas Energéticas e Nucleares/Comissão Nacional de Energia Nuclear (IPEN-CNEN) – Brazil and Instituto Federal de Educação, Ciência e Tecnologia de São Paulo (IFSP-SP).

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