BUILDING THE UNIVERSE IN FIVE ROOMS

1. INTRODUCTION

In the context of the European Unlock project, it was developed a prototype of a virtual Escape Room about Physics. The main aim of this escape room is to foster the role of the orders of magnitude of the basic physical constants in the fundamental laws of physics, as well as transversal skills such as critical and innovative thinking, intra-personal skills and organizational skills.
The target group was HEIs students, specifically in the field of sciences. Nevertheless, it could be adapted to other fields, but it would be necessary to give the students a basic introduction to the fundamental physics prior to the implementation of the game.
The duration of the Digital EER, on average, was 65 minutes (~13 mins per each room). Since it is a Digital escape room, the student can play in several sessions, whenever they want.

2. OVERVIEW

The game has five rooms, each of which is related to a fundamental area of physics (Thermodynamics and Statistical Physics, Gravitation, Electromagnetism, Quantum Mechanics and Relativity Theory), and it consists in deducing the fundamental laws of nature to build a stable universe right from the start. For each law constructed, one of the fundamental Planck constants is obtained, which serves as the key to access to the next room.
The protagonist of the game is Thanos, a homicidal villain and faithful follower of the Malthusian thesis on demographic catastrophes. He is convinced that the universe is badly designed and sets out to get the six infinity gems. Once he gets them, he gives his famous snap and makes the whole universe disappear, ready to create a new one. However, the gems talk to him and criticize his naivety, explaining that he will have to make very special physical laws to form a universe that can support life. In addition, he has destroyed very valuable information about the fundamental constants, intrinsic to every universe, whose value cannot be derived from any law, and which is also crucial for the emergence of life.
After that discussion, they agree to follow the following dynamic: Thanos has five chapters to create the universe. In each chapter, a fundamental constant will be revealed to him, and if he is able to make a physical law related to that constant, he will prove himself worthy and a new fundamental constant will be revealed to him, advancing to the next level.

3. PRE-GAME BRIEFINGS

The ERR has a linear structure: when you solve the puzzle of one room, you get the key for the next one (this key is a text code that is requested at the beginning of each room).

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4. DESCRIPTION OF THE EER

Materials/logistics:

The material needed for all sections is just a computer with internet connection, and a basic knowledge about fundamental physics.

Description of each challenge:

Thanos has five chapters to create the universe. In each chapter, a fundamental constant will be revealed to him, and if he is able to make a physical law related to that constant, he will prove himself worthy and a new fundamental constant will be revealed to him, advancing to the next level. The first fundamental constant revealed to him is Boltzmann's constant k.

Thanos accepts, and with the help of his "friend" Rick and the omnipotence of the gems begins by creating space, time and matter. Once he gives freedom of movement to the particles, he observes that matter is dispersed and ends up scattered throughout space, instead of forming beautiful astrophysical systems. To understand why this happens, he must understand the second principle of thermodynamics and deduce Boltzmann's law.

Having understood that without interaction between particles chaos is the norm, the gravitational constant G is revealed to him, and he sets out to put the particles into orbit. To do this, he must choose what the gravitational force will depend on (and in what form, i.e., whether it is a linear, quadratic or cubic dependence). In the end, by trial and error, he will arrive at Newton's universal gravitational force.

When he achieves stable orbits the electric permittivity constant ε is revealed to him, but he sees that only meteors form in his systems, not stars. Rick explains to him that he must find the rest of the fundamental interactions. Then Thanos decides to start with the smallest: atoms. Inspired by his beautiful gravitational systems, he sets out to make a hydrogen atom by orbiting an electron around a proton, attracting both by a force very similar to that of the previous chapter (changing the masses by electric charge).

However, just when it is created, it disintegrates emitting light (more specifically synchrotron Radiation). Although his atomic model has been a failure, the gems are satisfied that he has deduced the Coulomb force and reveal to him Planck's constant h .

Rick introduces him to the world of quantum mechanics. In this theoretical framework, he will have to make new models for atoms and their nuclei, and he will begin to understand the relationship between electromagnetism and light. In this way, he gets stars to form, and the constant of the speed of light c is revealed to him.

The surprise of the fifth chapter is that light always propagates at a limiting velocity that constitutes a fundamental constant c. Rick introduces him to the world of special and general relativity, in the context of explaining the precession of mercury, and Thanos begins to understand why Rick was hinting that gravitational forces could be proposed that depend on the speed of light, why black holes are formed, etc.

After this, the solar systems begin to stabilize, and life begins to emerge. But Thanos is no longer so sure that he wants to intervene in the demographic evolution of the species. After all he has learned, he prefers to observe his creation and test his dogma that the population can increase indefinitely by destroying all resources. In this way, the plot is brought to a close.

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5. FINAL REFLECTIONS

The evaluation process has been divided into two phases:

- Firstly, an assessment of the game was performed among a group of experts in the field of gamification, graphic design and game evaluation.
- Secondly, a dissemination among Physics students (first and second year) and among students of the master's degree on education (MAES UGR) was performed to assess the Escape Room.

During this testing phase, we have collected anonymous statistical data, which serve as an objective complement to weight the answers of a questionnaire at the end of the game. With these tools, we have focused the evaluation on the following points: Objectives achievement, game quality, and others interesting questions regarding gamification in the classroom.

The room with the highest error rate was the first room, with an average of 14 errors. Questions involving mathematical calculations and assimilation of physical concepts have had few failures, while the most common errors are of the logical type. This betrays a lack of clarity in some questions, which is solvable by slightly reformulating the riddles, giving more clues or giving immediate feedback.

The most negative opinions were found to come from students with the most errors made and the longest time taken to exit the EER. Although after the feedback from the experts the authors tried to improve the game so that it could be played in a fully automated way, the results of the second phase showed that this was not enough to be able to play the game without problems related to technical doubts. This issue, in fact, is one of the main conclusions that we reached in the unlock project after the WP7. This is the main problem that caused frustration and demotivation among the students, and it could have been avoided if the game had been supervised in real time instead of being designed in an automated way.

6. OUTCOMES / IMPACT

About the question: Do you think you would have learned more through a traditional method (master class, laboratory practice, seminar, lecture...) well designed with the same objective as the game?

• Yes (50% [4 students]).
• No (25% [2 students])
• Other answers (25% [2 students]):

“More than learning, the game allows you to reinforce what you have learned and above all to create a critical spirit. For example, you wouldn’t get the first screen if you don’t know the electromagnetic spectrum (which you have to have learned it)”.

“This is difficult to state. I think it is a very good complement”.

7. LESSONS LEARNED

The results make clear the importance of testing the EER before using it as an educational tool. This work is a clear example of how a game can have a coherent narrative, interesting content, and a correct design, but not yet be ready to fulfill the objectives for which it was designed. Specifically, in this work, we have identified the need to supervise the game during the students’ participation, in order to maintain their motivation and allow them to benefit from this educational tool.

Since it is a virtual game, it could be monitored through a meeting platform such as Google Meet, Zoom, Microsoft Teams, Blackboard or any other. The only limitation is that two students cannot play at the same time, unless they connect from the same device, so the game would not be optimized for

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team play.

8. CONCLUSION AND FUTURE OUTLOOK

As indicated in the previous point, a third evaluation phase may be of interest for future research. In this third phase, the game would be launched to a larger number of students, and each of them would be supervised live by the authors in order to provide immediate feedback. A large participation would make it possible to reach more conclusive results than those presented in this chapter.
Of course, improvements can be made concerning the design of the interface and characters. It would also be interesting to add a voice narrating the game for visually impaired students.
With respect to an extension of the content, as suggested in the point where the narrative is discussed, one could start a second part of the game by talking about complex systems in physics. In the context of the game, it would be introduced to study population dynamics, but it could be generalized to other physical systems. For example, it would be interesting to talk about the three-body problem and discuss the stability of our solar system. Particle physics, large-scale astrophysics, quantum field theory, and even scientific formalisms that need not be directly related to physics, such as biology, geology, chemistry, or applied mathematics, could also be covered in detail.
Finally, it would be interesting to test different platforms for programming the game, which would allow easier simulations and would be optimized for data analysis. It could also be interesting to program the game with 3D animations, and that the player has a certain freedom of movement, in order to overcome the criticism of some experts of the lack of personal initiative in the game.

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