RADIOMON – ISOTOPES, RADIATION AND NUCLEAR TECHNOLOGIES IN A NEW GAME FOR THE I-GENERATION

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Making pupils enthusiastic to learn more about science, technology, engineering and mathematics (STEM) is a challenge, and the small population of STEM students is often unaware of the scientific and technological aspects related to radioactivity. The underlying goal of this project is to create interest in nuclear technologies and their fundamental science via a videogame that has also the ambition of becoming a teaching tool. The paper introduces the retained idea of an original videogame with well-defined learning objectives, discussing its benefits and challenges. The long term vision is not limited to one videogame but rather a properly developed franchise to open up infinite possibilities of different story lines where all the different facets of nuclear science and technologies could be addressed. This effort requires the cooperation of skilled developers and numerous nuclear stakeholders to reach the desired effect.

1 Introduction

In these last decades, the word "nuclear" has often been connected to negative connotations by the general public in a popular thinking. The use of nuclear technology for warfare purposes has not yet been forgotten, and the many benefits brought by its peaceful use for electricity production are overshadowed by accidents. As an additional factor, nuclear physics and associated technologies are seldom easy to understand; whilst sciences of macroscopical phenomena can often be spectacular, the effects of decay, fission, fusion or other nuclear phenomena are intangible, odourless and not even visible with microscopes. These characteristics demand even more abstract thinking, which can be, without appropriate guidance, a difficult exercise for many students. The already small population of potential STEM pupils and students are often left unaware of this field as they are not broadly introduced to nuclear science and technologies in their secondary school studies and do not have means to visualize the physics. These youngsters would rather turn their attention to either more popular technologies for the same purpose, e.g. wind turbines, which is socially accepted as a good technology to combat climate change, or more sensational, e.g. rocket engineering if they are attracted by exciting challenges.

Nowadays, innovative video materials succeed in visualizing nuclear phenomena and more investment could be allocated for developing these tools into teaching means for complex concepts. Indeed, the target group of these media is intended to be large and in certain cases they succeed in reaching a large population, as for example [1].
Nonetheless, within the large amount of media material available on the social networks, the impact is not enough and cannot be compared to the direct effect that the perspective of a Mars exploration can have on a young mind.

The authors of this paper share a wish to attempt broadening the circle of people that could have an interest in nuclear physics while rendering the topic more popular. The objective is to find a way to reach a large population among those promising young pupils and students that still have to choose their study and career path.

The possibilities to integrate nuclear phenomena into a videogame have been explored. The direct objective is therefore to teach to the younger generations basic nuclear and radiation physics and to let them discover nuclear technologies in the fun environment of a videogame, without stressing the learning possibilities when distributing the product but accurately integrating them and declaring them as such. The primary target group are teenagers, for which videogames are an effective means to reach a large population, but by extension the game can be played by all age categories. The other reason for which videogames are chosen is their potential to visualize phenomena such as radiation decay and elements such as radionuclides in an attractive and accessible way, as they benefit from artistic freedom. At the same time the player learns-by-doing, if the game is designed such that the game's objectives are aligned with the learning objectives. The next chapter discusses what the gaming industry already produced.

2 Discussion on explored options

One of the most popular options to attempt a connection between the subject and the mean is to insert the danger of radiations into a realistic **action game** (i.e. games with one main character in first person carrying out different tasks/quests), which would make an interesting concept allowing to discover technologies and learn radiation protection in a simulated environment. Nonetheless, it remains a limited approach, highlighting the negative effects of radiations, which we do not strive for, and moreover it has already been adopted in the past. The most significative and popular game that has already integrated the danger of radiations is undoubtedly *Fallout*, where the main character would roam in areas that may be highly radioactive, measuring the radiation levels with a Geiger counter and collect a radiation dose (in rads) that affects the skills of the character. To render the concept "playable" though, several features were invented, as the possibility to remove rads by taking medicines, or that people, instead of dying of radiation sickness, would become ghouls, zombie-like creatures that may even glow. Indeed, the whole environment was reflecting a post-nuclear-war apocalypse wasteland.
Besides the simplifications, that are justified for playability reasons, this sort of apocalyptic vision created by *Fallout* is feeding the common negative perception on nuclear, which we intend to counteract.
Therefore, we discarded any inclusion of radiation into post-apocalyptic scenarios.

Some games were specifically created to simulate nuclear reactor functioning or the environment of Chernobyl after the accident, with a concept similar to Fallout. These games remain for niche public and most present the negative connotation too. The desired setup is rather the one of a more casual game, which is accessible for all and especially for those who desire to have some fun without investing too much time in the game.

Theoretically, any action game could host radiations, even **platform games** as Super Mario or **sandbox games** as Minecraft, and indeed choosing a successful franchise would maximize and guarantee the reach. The obstacle found on this path is to contact the major producers of such videogames and, even if we surmounted such obstacle, convincing them of the added value of integrating radiation for the game itself and avoiding another title as "Fallout" (especially in terms of invented facts) are even bigger risks that we cannot face at this stage.

Developing an original game is the best solution to avoid unwished twists of reality. The option of realistic action games becomes though unaffordable, as such games require a big effort in terms of resources (see Figure 1).

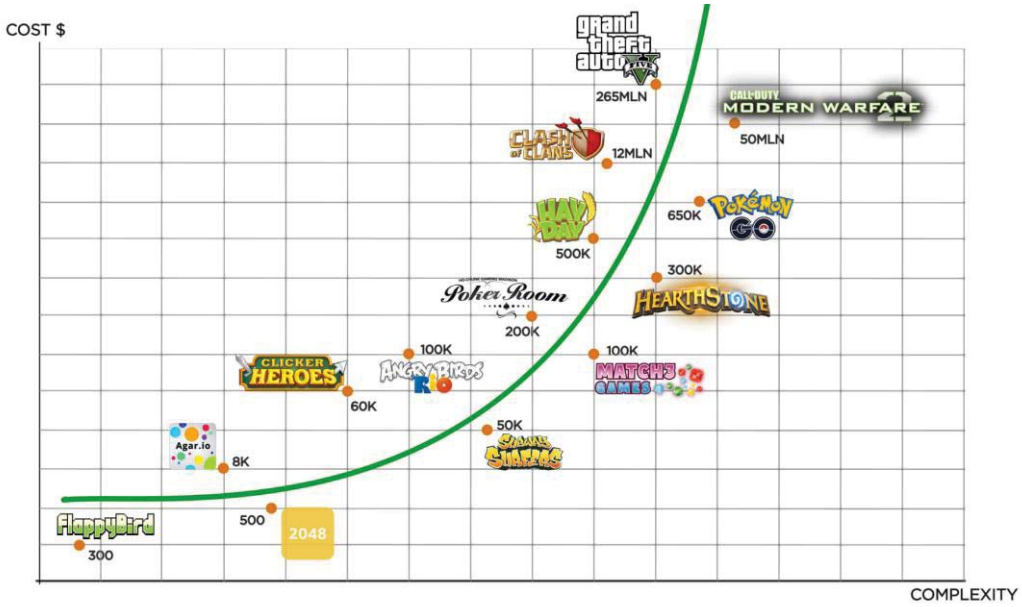

Figure 1. The cost as a function of the development complexity follows an exponential trend [3].

A more abstract and artistic idea consists in the attempt to visualize nuclear phenomena and give a face to radionuclides. As each radionuclide has its own characteristics (atomic number, size, half-life, decay types, energies of emitted particles, cross-sections) one can imagine that each of them represents a separate character, with its own features and personality. This leads to a direct association to a very popular franchise that also produced videogames, i.e. Pokémon.

Pokémon is categorized as a "**monster-collection Role Playing Game**" and it has inspired similar concepts along the years. We argue here that their success is connected to the aspect of collection. At the light of this incredible success, the following question was raised: why inventing imaginary characters when nature offers us the chart of nuclides?

Radiomon is a concept loosely inspired by Pokémon, that will probably become a mix between a monster-collection RPG and a strategy game, as the player will have to choose in advance the best Radiomons from the collection.

Lastly, the choice of the platform on which the game will be developed is driven by the wish of greatest accessibility to a large audience, which nowadays is guaranteed on mobile applications for free download. This is supported by the data retrieved from the gaming industry [2], that indicate an important rise in the mobile gaming section of the market, leading us to focus on a game supported by a mobile app.

3 Retained approach

In Pokémon the characters are evolving thanks to the experience gained in battles: each of them has one or more types of attack, with associated attack points, and to protect itself from the adversary it has defence points and, together with its life points, the resilience to the adversaries' attacks is determined.
Few of these properties can be associated to Radiomon properties: types of attack are decay types and attack points are decay energies. Their evolution occurs via decay after a specific time or particle capture, which is intrinsically defined by a property called the "cross-section".

These three properties (decay time, decay energy and cross-section) make the concept viable for a time-driven game in which the mastery of the cross-section will allow the player to trigger the best physical effects to win the game. Indeed, it is by activating Radiomons that decay energy is emitted against the target.
With this basic concept, the purpose can be flexible, let it be a fight between two teams of Radiomons or a task of sending the decay energies towards a target as a tumour cell in the allotted time. At this stage, the project is consulting with game developers to determine the best goal for the player.

As the concept should be synonymous of fun, consistently with a casual game, we identify here below the elements that we think will bring joy to the player:

- Collection: there are more than 100 elements and potentially hundreds of radionuclides – the objective to have a full collection of characters can be the main drive for the player.
- Hitting the spot: sending a ball to a goal is the most popular form of entertainment in the world. In this game: the ball is the incoming particle and the goal is the cross-section.
- Fun visuals: all nuclear phenomena being invisible, they can be visualized in an entertaining manner without restrictions associated to reality.
- Storytelling: we are preparing to important discussions with the developer to include a story-telling that may link the game to the discovery of technology and history, through dedicated missions to accomplish or modes of collecting the Radiomons.

In the most basic concept of the game, the player can carry out the following actions: the choice of the Radiomons based on the acquired collection, their activation by "feeding" them a neutron and the use of shielding equipment, which is consistent with the concept of a casual game. Nonetheless, to be more successful in the game, the knowledge of the three properties (decay time, decay energy and cross section) is a must. This has the purpose of stimulating the curiosity of all the players which, in order to win, will gladly try to remember by heart which Radiomon has a higher fission cross-section or most energetic gamma rays, for example.

3.1 Learning objectives

This leads us to list the learning objectives of the basic concept into 3 categories:

- nuclear physics, the properties of the Radiomons.
- radiation protection: as the decay particles are sent, they can be stopped interacting with the environment, which will be used to let the player learn basic concepts of radiation protection in the game.
- chemical compositions: one last important aspect to be addressed by this game is the association of the Radiomons to the reality. The player should not lose contact with the context of the game, lest he/she will start thinking about magics rather than nuclear physics. The collection method within the game will therefore be linking real-life objects, either common or specific technologies, with the Radiomons. E.g., from water one can extract two hydrogens and an oxygen, while inside a nuclear fuel pellet the same oxygen can be found together with uranium.

To assess if the player actually learns the three aspects (nuclear physics, radiation protection and chemical composition), we will use the game prototype together with a "before and after" test.

4 Challenges

The main challenge identified for this project is the market competition: a game has to be a flawless, attractive and engaging product and many other games in the market have these characteristics. The necessary condition is therefore to achieve a high quality gameplay within the final product.

In fact, although the game concept is rather unique, the choice of mobile games in the app store is such that the average player will tend to choose only the most popular options, i.e. high rating and number of downloads. The associated risk of a failure is the loss of investment and a lower-than-expected reach among players.

Among the major goals of the concept there is to visualize the radionuclides in an impactful way: inspiration for this goal is the famous cartoon series "Il était une fois…la vie" from 1987 [4], where the human cells were "humanized" to explain how the human body works. The challenge here is to create meaningful representations of the Radiomons, easily recognizable, and conceptually consistent with their nature: all gases shall have similar look, all metals shall have a shiny appearance, stable nuclides will look dormant while radioactive ones distressed, the cross-section can represent a visual feature of the nuclides, and so on.

Simplification of reality is inevitable in games and this concept is not left untouched. For playability purposes, the following points are necessary simplifications:

- the decay time is a fixed time rather than a half-life,
- decay particles don't scatter in air and travel "forward" undisturbed in a straight line until the target,
- the number of decay and capture modes will be limited and the energy dependence minimized
- sizes and distances are adapted to the dynamics of the game.

For each of these points additional media material, e.g. edutainment videos, should be created to explain the reality and why it has been modified within the game.

Finally, the objective to realize a profitable product which is educative and realistic on one hand while presented as a casual game on the other hand does not have many precedents and it will require a good and balanced effort between conceptualization, development, marketing and dissemination.

5 Roadmap and long term vision

The project has concluded an *exploration phase* where the interest of nuclear organisations was confirmed and possible developers were consulted.
In the current phase, the *definition phase*, the high level concept has been completed and presented for discussion to stakeholders and developers, with the objective to obtain a prototype version to be tested before proceeding into the full development of the product.
During an *acceleration phase* we will therefore determine the basis for the product that will be commercialised at the end of the next phase.
The flexibility of the concept proposed allows a *scaling-up* of the concept, where we could twist or adapt the product into other versions with a more educational purposes or other dedicated tasks. The long term vision is therefore not limited to one videogame but rather a properly developed franchise to open up infinite possibilities of different story lines where all the different facets of nuclear science and technologies could be addressed.

6 Conclusion

Having debated the possible benefits that a game for a broad population would bring to both the society and the nuclear scene, this project is of high interest. The major challenge being found within the market competition, the necessary condition for a success is the high quality of the product. We call for an extended collaboration among the nuclear organisations to share the risks as the benefits will be common for all.

Our original approach relies on the support of experienced game developers and, most importantly, the cooperation of numerous nuclear stakeholders for this effort of creating, branding and spreading a product that would have the ambition of "giving a face" to all the radionuclides and decay particles and give visibility to nuclear technologies to benefit the whole nuclear industry, healthcare and research organisations.

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