

Game design for environmental awareness – the case of “Invasive Plants”

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ABSTRACT

Invasive species are a major environmental problem affecting Portugal and the rest of the world. As such it is important to promote scientific literacy and environmental awareness on this topic. In this article we present a serious game for environmental awareness, *Invasive Plants*. The game’s goal is to eliminate several invasive species using the appropriate methods. Through engagement with the game, we intend to promote awareness for the resolution of an environmental problem caused by invasive species. Usability tests have revealed that this prototype has educational potential, however, improvements are still needed, such as how the information and mechanics of the game are presented and extending the content.

KEYWORDS

Serious games;
Pervasive games;
Location-based games;
Environmental awareness.

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1. INTRODUCTION

Scientific dissemination can take place in many ways, but all aim to convey a scientific message to the general public. Nowadays, the way people acquire knowledge has changed, as well as their openness to digital media. There are several theories that focus on what motivates a person to consume a particular media product or the media in general. Gamification techniques and games have proved to be effective in motivating and engaging people with media content. It is no surprise they were adopted for purposes other than mere leisure. Serious games have a goal that goes beyond entertainment and can be used for educational and awareness purposes, among others (Michael & Chen 2006; Marsh 2011).

In this technology age, smartphones are multipurpose portable platforms (Santos et al. 2016), which include an increasing number of functionalities (Pereira 2013). In addition, they have been massively disseminated through society and can be an adequate means of promoting scientific dissemination *in loco*.

Current technology allows us to overcome the barriers of space. Location-based serious games enable players to explore the real world around them while playing a game that is meant to educate them on some subject or make them aware of some real problem. There are several games that provide these types of experiences for urban contexts, under the theme of cultural heritage. Likewise, games can also be an asset in the creation of new experiences in spaces of nature, helping to promote a place's natural heritage and fostering environmental awareness (Santos et al. 2016).

We live in a society of digital information, knowledge and social interactions, which have changed the way people seek experiences and acquire knowledge (Santos 2017). Consequently, the way in which content is produced for different areas has also been changing in order to respond to this demand. In addition, while the latest generation of smartphones has unprecedented potential to change the way we interact with others and the environment (Jepson & Ladle 2015), this transformative power, and their potential for educating people on nature and its topics, have not yet been fully explored.

As the use of pervasive games on mobile devices reveals a great potential for environmental awareness, and given the limited number of published studies on this field, this topic becomes relevant, needing further investigation. Spreading awareness about natural heritage through the use of information and communication technologies is, therefore, a challenge to the scientific literacy of the postmodern world, as well as a need (Santos 2013). For this reason, it is considered relevant to contribute to the exploration of new

ways of communicating science, with contents of environmental awareness contained in the form of location-based games, an area that although not new, still needs more study (Weber 2016).

The object of this paper is integrated in a digital media doctoral project, on the use of the serious pervasive games for the scientific dissemination of natural heritage. In this article, we present one of the minigames developed over the course of this research: *Invasive Plants*. This game was designed for the general public but, since it's still in its early stages of development, it was tested by a sample of game developers. The reason is to gather more informed feedback and suggestions for future improvements. That way, after the technical problems are solved, we will be able to focus more on the game's message efficiency.

This paper will begin with a brief literature review on serious games and location-based games and their importance, with emphasis on their use for educational purposes, scientific dissemination and awareness for nature and environmental issues. Some examples of mobile applications with this type of games are also discussed. Afterwards, the game *Invasive Plants* is presented, as are its technical specifications, gameplay, mechanics and objective. Afterwards, the game evaluations and their results are presented. At last, we conclude with a discussion and conclusion about the user tests results.

2. LITERATURE REVIEW

The following literature review intends to provide a general background about serious games for nature dissemination and environmental awareness in society.

In today's media culture, digital games, gamification, pervasive games and serious games enable new forms of gameplay and lead to what Raessens (2010) calls "ludification of culture". Like other forms of media, games have the potential to be more than just entertainment (Michael & Chen 2006), as they can also pass on a message, teach something or provide an experience (Michael & Chen 2006; Marsh 2011).

2.1 SERIOUS GAMES, PERVASIVE GAMES AND PERVASIVE SERIOUS GAMES

When digital games have the ability to take game experience from the virtual world into the real world, they are called pervasive games (Benford *et al.* 2005; Viana *et al.* 2014; Jantke & Spundflasch 2013). In the case of location-based games, the experience is adapted based on the information the device receives about the physical location of the player, usually by means of a GPS sensor, allowing the player to access location-specific information, such as maps (Jacob & Coelho 2011).

1. INTRODUCTION

By combining the physical and virtual world, pervasive games promote new types of game experiences (Kuehn & Sieck 2009; Baptista *et al.* 2015), which extends Huizinga’s traditional “magic circle”. With the development of positioning technology in mobile devices, this type of games found a gateway into the mobile market (Pereira 2016). The most well-known example of a pervasive game is *Pokemon Go* (2016), developed by the video game producer Niantic and published by Nintendo. However, not every location-based game has entertainment as their main goal. Location-based games that have an intended goal of educating people on a certain theme or promoting awareness on a real issue can be called serious pervasive games. For example, the *Savannah* game allows learning about lions’ behavior through collaboration among players, thus exploring a more educational component (Benford *et al.* 2004).

Many of these games were designed for urban environments and museums, and are associated with spreading awareness about Cultural Heritage and address issues related to History, Architecture, Art and Culture. One example from Portugal is *TravelPlot Porto*, an urban tourism application with a location-based game for mobile devices, which consists of a treasure hunt through the city of Porto, having several monuments and relevant points of the city as a reference (Ferreira & Alves 2012).

Serious pervasive games can now be used for scientific dissemination (Santos *et al.* 2016; Santos *et al.* 2017) as a way of motivating contact with scientific knowledge in a given context. In this way, it is believed that it makes sense to apply the serious pervasive games in natural environments for the dissemination of Natural Heritage.

2.2 PERVASIVE SERIOUS GAMES FOR NATURE DISSEMINATION AND ENVIRONMENTAL AWARENESS

Pervasive technology allows amplifying and enriching the experience of visiting natural spaces, since a layer of digital information is placed over the real world, highlighting contextual information about these spaces.

Mobile applications in the context of nature tourism in Portugal typically have a map of the region with routes and trails, information related to points of interest and, sometimes, information on local fauna and flora (Santos *et al.* 2017). The authors give as exam-

ples the *National Parks Wildlife Guide*⁴ application, which shows the wildlife of the North American parks, and the *National Parks*⁵ application from National Geographic, which presents an interactive guide and maps of the most visited parks of the United States of America. Some examples from Portugal are the *Trekking BioRia*⁶ application which recreates the walking and cycling routes of Estarreja and the application for Pico's Natural Park, which presents the landscape of the this island's vineyard culture and its Natural Park. However, Santos *et al.* (2017) concluded that in these applications, gameplay is not explored.

Awareness-raising games linked to nature are scarce. In the area of school education, however, we can mention the application *EduPark* (Rodrigues *et al.* 2017), which allows one to know more about the Infante D. Pedro Park, in Aveiro, Portugal, through questions triggered by augmented reality.

Serious location-based pervasive games have a potential for education and communication of any area of knowledge. We believe that Natural Heritage and environmental awareness are very relevant themes for creating contents for this type of games, applied in natural spaces. Since the gaming experience is related to the real and physical world, it is believed that location-based games can make users more aware of the environment around them and more open to environmental issues addressed in the content of these games. However, further studies are needed to confirm this hypothesis.

3. METHODOLOGY

We developed an environmental awareness game about invasive species. The following methodology describes the chosen theme, the technical specifications of the game's development and the data collection process.

⁴ National Parks Wildlife Guide, available at: https://play.google.com/store/apps/details?id=com.enature.guides.npca2&hl=pt_PT, 2018

⁵ National Parks, available at: <http://www.nationalgeographic.com/mobile/apps/national-parks-by-national-geographic/>, 2018

⁶ Trekking BioRia, available at: <http://www.bioria.com/newstext.php?id=222>, 2018

3.1 GAME DEVELOPMENT TECHNICAL SPECIFICATIONS

The game is designed for Android mobile devices and to be played in a horizontal (or landscape) position. The Unity 3D game engine was used. All visual elements were drawn through the use of the Adobe Illustrator vector drawing software. For the sound effects a search of sounds (fire, explosion, dry leaves, end of the game, among others), was carried out in open source databases and later edited with Audacity.

3.2 EVALUATION OF PROTOTYPES/ PROTOTYPE TESTING

After the development of the first prototype, an initial evaluation of its usability was carried out, during an event aimed at game developers. Three Android mobile devices were used with the application previously installed. Thirty-three users participated in this experiment, each test having an average duration of ten minutes. Each user was encouraged to explore the application. For data collection, a questionnaire survey methodology was adopted, in which, after each test session, the participants were asked to complete a questionnaire about their experience.

After analyzing the results of this first evaluation, some changes were made to the game's prototype. Following these improvements, the prototype was re-evaluated through a second test phase. This also took place during an event of game developers. Once again, three Android mobile devices were used with the application previously installed. Thirty users participated, each test having approximately the same duration. The experiment protocol was the same as in the first phase of testing. The questionnaire survey was also the same, except for an additional question that was asked to see if the user had already participated in the first testing phase.

Eight of the analyzed issues have made use of a Likert scale, adapted for a semantic scale ("I strongly disagree", "I disagree", "I have no opinion", "I agree" and "I fully agree"). In addition to age and frequency with which they use mobile applications, participants also had to answer if they felt the need for an instruction manual or tutorial, if the application responded quickly to the user and if the game responded as expected to input, if they noticed the game's purpose and message, as well as their opinion about the game's educational component's effectiveness and if they found it entertaining. They were also asked if they would like to play more levels, whether they liked the game's visual aspect, which age groups they considered most appropriate for the application and, finally, they were encouraged to write comments and suggestions.

4. THE GAME INVASIVE PLANTS

In this section, we present the theme, the game purpose, the interface and the game description.

4.1 THEME AND GAME PURPOSE

The chosen theme was invasive species, as it is a major environmental problem affecting Portugal and the rest of the world. The game's main objectives are to promote scientific literacy and raise awareness about the environmental problem caused by invasive species. Through this game we intend, although in a purposefully simplified and caricatured way, that the player learned to identify some invasive species, as well as learning methods for their control and eradication. The game's idea is to destroy invasive species with the appropriate methods. Several levels were considered (see figure 1), each containing an invasive species, with the combination of multiple invasive species being a possibility for later levels. However, due to limitations of resources and time, only the first level was developed, concerning the invasive *Eichhornia crassipes*, known as water hyacinth.

Water hyacinth⁷ is an aquatic floating herb, with swollen leaves and very showy blue-violet flowers. Originally from South America, this plant represents a very high level of ecological risk, as it multiplies quickly forming a thick carpet that floats and spreads in all directions, causing the fish to eventually die from asphyxiation due to a lack of oxygen. Several techniques have already been attempted to eradicate water hyacinths, such as the use of dynamite, flame-throwers, floating harvesters, among others, but all these have been ineffective.

4.2 INTERFACE AND GAME DESCRIPTION

The *Invasive Plants* game prototype was structured according to the wireframe seen in figure 1. The prototype starts with the initial menu with four options: "Play", "Information", "Credits" and "Exit game" (see figure 2).

⁷ This description was based on the Website <http://invasoras.pt/>, the Portuguese resource of scientific information for Invasive species in Portugal. The Website also explains that the Water hyacinth is listed in Annex I from the Portuguese Decree-Law No 565/99 of 21 December and is included in the list of species of concern in the European Union by Regulation (EU) 1143/2014 of the European Parliament and of the Council of 22 October 2014, because of its level of ecological risk.

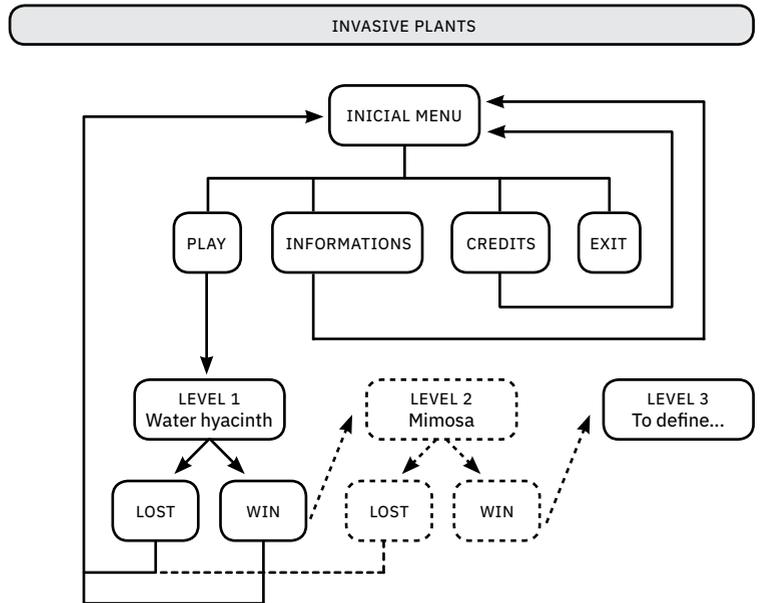


Fig. 1
Invasive Plants game prototype
menus wireframe



Fig. 2
Menu interface with
“Play”, “Info”, Credits”
and “Exit game” buttons

By touching the “Info” button, the player has access to more information about the water hyacinth, how to eliminate it and the game rules. In “Credits” the list of elements of the game design and development team is presented. When you touch the “Play” button, the game starts with the first level. If the player loses, a game over screen appears and the player is returned to the initial menu. If the player wins, a victory screen appears, and the player can continue the game on the second level. This logic is repeated as many times as the number of implemented levels. Due to time constraints, it was only possible to develop the first level. This level starts with a

lake's scenery, with some fish, aquatic plants at the lake's bottom and water hyacinths. These float on the lake's surface, distributing themselves horizontally with their roots under water. After some time, they reproduce naturally, regardless of the player's actions. The vertical bar on the right symbolizes the "health" of the player, this being the amount of oxygen in the lake, which is influenced by the number of invaders. The larger the number, the less health the player has, and the murkier and darker the lake's water becomes. Thus representing its eutrophication, until when the life bar becomes empty and the player loses. The number of water hyacinths also affects the fish, which can die if there are a high number of plants in the lake. The scenario also includes an inventory with four tool options, which the player can use to attempt to eradicate the water hyacinths: a bomb, a net, fire, and an axe. These tools were not chosen randomly. The dynamite, for example, has already been used in real life in an attempt to eliminate these plants with disastrous effects. The tools available at each level will not be exactly the same and will depend on the actual methods of eradication for each invasive species. When dragging an object from the inventory, it will exert its effect on the water hyacinths (see Figure 3): the bomb causes an explosion that multiplies the water hyacinths; the fire and the axe are not effective because the plants are in the water, leaving the net as the only effective option. If a bomb bursts at the beginning of the game or at the maximum health level, the player's health drops substantially, but not to the point of ending the game.

The player must drag the net in order to remove the water hyacinths from the lake and allow them to dry. After a second, the water hyacinth is dry (see Figure 4) and disappears. As soon as the player eliminates all water hyacinths, (s)he completes the first level and a victory screen appears. In more advanced levels, the player will have to be careful not to destroy indigenous species otherwise he will lose "health".

Fig. 3
Tool effects on water hyacinth:
bomb, fire/axe and net

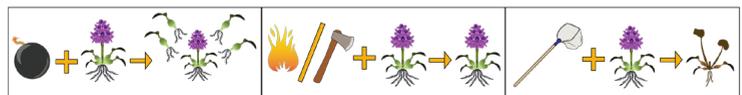
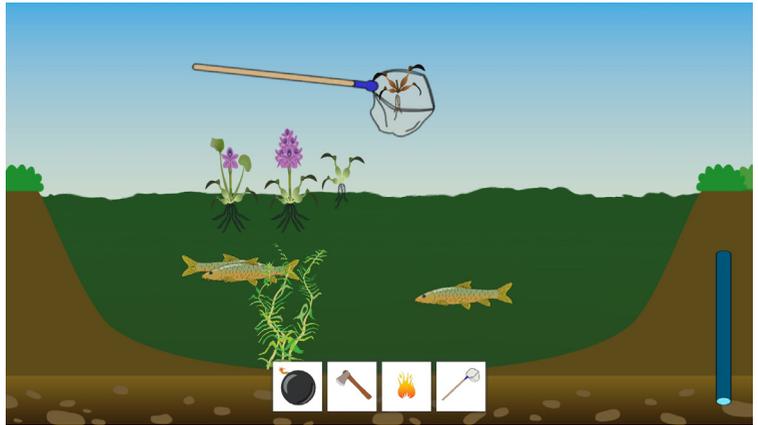


Fig. 4
Game interface after
collecting a water
hyacinth using the net



The game mechanics are not location-based but the game itself will be. The idea is for this game to be unlocked in a place inside the Gaia's Biological Park that is dedicated to environmental awareness on the subject of exotic and invasive species. Nonetheless, it has the potential to be an isolated app without the location-based component.

In future levels, there will be different invasive species and upper levels could even have a mix of species. The tools and mechanics would be adapted to each species. Some of them can also have more complex mechanics of elimination. For instance, for a mimosa tree it would be necessary 2 steps: first, to peel its bark so that the tree could dry out, and after, to chop it with an axe. The level of life of the player could be measured by the amount of water on a nearby spring. The idea of these levels is to recreate the mechanics of real life in an educational and gamified way.

5. RESULTS

In this section, we present the results obtained via the used data collection instruments. It is important to note that since the sample is not representative, the results do not allow definitive and generalizable conclusions to be drawn.

There were 33 users on the first phase of the test and 30 on the second. The users' age from the first round of tests varies between 15 and 47 years, with a mean of 29.8 years. On the second test phase, the participants' age ranged from 22 to 45 years, with a mean of 29.6 years. According to the results, most respondents from both phases of testing use mobile applications frequently. The results to the questionnaires referred in section 3.2 are summarized on Table 1. The results present the percentage of users that "agree" and "fully agree".

Table 1
Results from the
1st and 2nd phases of testing

QUESTION	1 ST PHASE	2 ND PHASE
Need an instruction manual or tutorial.	58%	50%
The application responded quickly.	76%	93%
The game responded as expected to the controls.	51%	74%
The purpose of the game was easy to understand.	54%	60%
I understood the game message.	75%	83%
The game has an effective educational component.	76%	80%
I thought the game was fun.	48%	80%
I would like to play more levels.	88%	96%
I liked the visual aspect of the game.	85%	84%

As shown in Table 1, the need for an instruction manual or tutorial decreased 8% in the second phase, compared to the results obtained during the first phase. Participants considered that the application responds quickly. In other results, the percentage of disagreement with the sentence declined by 15% in the second phase of testing and the percentage of fully agreeing with the claim rose by 34%. Practically half of participants in the first phase agreed that the game responded as expected to input and there was a 23% increase of positive responses in the second phase of testing. Regarding the clarity of the game's goal, the general opinion is divided both in the first and in the second phase, although it presents some improvements in the second phase. Nonetheless, it was found that they were more consensual in their opinion regarding the clarity of the game's message. The percentage of users who perceived the message rose from 75% on the first phase to 83% in the second phase of testing. In general, participants considered that the game had an effective educational component. The percentage of users who considered the game to have an effective educational component increased from 76% to 80%. There was a significant increase from 48% to 80% in those who found the game to be fun. The vast majority of participants in both phases of testing expressed that they would like to play more levels, with an 8% increase in the second phase, from 88% to 96% of positive responses. The visual aspect of the game was highly praised in both phases of testing (85% and 84%). Also, the majority of participants considered that this game would be more suitable for a young age group, under 18 years old (88% in the first phase of tests and 90% in the second phase of tests). As the age group increases, the percentage of responses decreases. It was found

that 27% of the users of the second test phase had already participated in the first phase.

The survey included an open answer question, allowing participants to write comments and suggestions regarding the prototype and their gaming experience. Several comments expressed the participants' willingness and desire to play more levels and more variety of game content. Several comments from both test phases pointed to the lack of information and instructions in the game. It was suggested that before the player starts the game, they would be presented with information regarding their goals, the invasive species and the effects of each tool. Gameplay and mechanics problems were also pointed out in the first phase of tests, as well as suggestions for improvement, such as the fish being affected by the player choices (such as the bomb), adjustments to the game's difficulty and to improve feedback from user interactions. These and other improvement suggestions were taken into account during the second iteration. Among them: changes to the controls in order to allow the player to drag the tools; the adjustment of some values, such as the number of plants with which the game starts; the number of water hyacinths that spread with the explosions, as well as their influence on the "health" level; fish eventually dying as "health" dwindles; correction of some bugs; inclusion of more sounds; general aesthetic improvements. In the second testing phase, some comments were collected which indicate that when a water hyacinth is in the lake's right corner, it is a little difficult to collect it due to the net's length. One suggestion is for the net to be guided by a central axis so that it is possible to guide it to the left or to the right.

In the first phase of tests, some correlations were found between liking the visual aspect of the game, wanting to play more levels and finding that the application responded quickly to the user. Other correlations have been found such as between finding that the game needs a tutorial or instruction manual correlating with not realizing the goal of the game or thinking that it responded as expected to input. Other correlations found in the first phase were finding that the game has an effective educational component and perceiving its message, as well as finding it fun. In the second phase of testing, both perceiving the game's message and wanting more levels are correlated with liking the visual aspect and finding that the game has an effective educational component. In addition, the perceived message of the game also correlates with finding that the application responded quickly to the user as well as understanding the game's goal. Understanding the game's goal,

in turn, has a negative correlation with feeling the need for a tutorial or instruction manual. There was also a correlation between finding that the game responded as expected to input and finding it fun.

6. DISCUSSION AND CONCLUSION

Invasive species are a major environmental problem affecting Portugal and the rest of the world, so it is important to promote scientific literacy and environmental awareness on this topic. For this reason, the game *Invasive Plants* was developed. For the moment, the game prototype only has one level, focused on the invasive species *Eichhornia crassipes* or water hyacinth. The first usability tests provided clues on how to improve the game mechanics and dynamics in the second game iteration, and the second tests also provided clues for future improvements.

Taking into account that these are the first prototypes, it was considered relevant to gather the opinions of an audience with expertise in the areas of game design and development (developers) although both samples are not representative and do not match the target audience (park visitors). This way, with the project in an early stage, it is easier to make improvements and create a new prototype, more complete and refined, to be tested in the future by the target audience.

The results showed that more than half of the participants in the first test phase and half of the participants in the second phase felt the lack of an instruction manual or tutorial and part of the comments and suggestions obtained in the open answer question precisely referred to this topic. Although instructions and more information were added on the information screen in the second iteration of the game, they required that the player would consult them before playing, which rarely happened because of the participants' willingness to start playing, so not all participants realized the goal of the game. This can be solved by including in-game information before the game starts.

The effective educational component was one of the strengths pointed out by the participants. By having the freedom to explore the game mechanics, the users realized the effects that each method had on the water hyacinths, as well as how to eliminate them. The message was perceived by most users, especially in the second phase of testing, and in a fun way. However, about half of the participants in the first phase and slightly less than half of the participants in the second phase did not claim to find the game fun. This result points out toward a need to review the game mechanics and explore more options to make the game more engaging. It should

be taken into account that user tests were not carried out with the target audience, but mostly with creators and consumers of entertainment games, so there may have been some bias in the results. The fact that tests did not take place in the Biological Park of Gaia, where the game should trigger, may also have some influence on users' appreciation.

The results revealed that the vast majority of participants expressed that they would like to play more levels. These results are reinforced by the submitted comments, in which one portion suggested the addition of more levels and variety of contents. On one hand, this is considered a positive result, since it could mean interest, curiosity and motivation to continue playing and, consequently, greater knowledge acquisition or more opportunities for environmental awareness. On the other hand, it may also mean that the game still needs more content to become interesting, appealing and/or fun for some players. The graphical aspect was highly praised during the user tests, which is confirmed in the results obtained. Since most participants liked the game's visual aspect, it can be considered that this result provides clues as to which type of graphics should be chosen for games of this nature: simple, 2D, with easy to identify sprites based on their real-world counterparts.

To conclude, the obtained results were positive and provided clues that contribute to the game's future improvement and its adoption after the conclusion of this research work. Some of these improvements include the addition of in-game information and tutorials, the implementation of more involved mechanics, and some bugs' correction, which were not possible due to time constraints. It can also be considered that the evaluation tests, when performed with a more representative sample of the target audience would be more conclusive and illustrate more clearly the qualities and problems present in the prototype. In the future, we intend to do new user tests on a Biological Park with the target audience in order to test the usability. When the game becomes location-based we will study how the inclusion of the location component affects the user experience. The idea is for this game to be unlocked in a place inside the Gaia's Biological Park that is dedicated to environmental awareness on the subject of exotic and invasive species. The game mechanics are not location-based but the game in itself will be. Although this game can be played anywhere and be an app by itself, we believe that being part of a bigger app with a set of serious games, unlockable in places that have something to do with the subject of each game, will enrich the game experience.

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