Design Guidelines for Learning Games: the Living Forest Game Design Case

Luís Lucas Pereira
CISUC, University of Coimbra
Polo II – Universidade de Coimbra
3030-290 Coimbra, Portugal
lpereira@dei.uc.pt

Licínio Gomes Roque
CISUC, University of Coimbra
Polo II – Universidade de Coimbra
3030-290 Coimbra, Portugal
lir@dei.uc.pt

ABSTRACT
Games have long been known for their potential in learning but, on the other hand, design challenges and issues in their use in real contexts have been recognized as well. In this paper we report on a design case for a learning game, "Living Forest", targeted at exploring sociotechnical aspects of the relationship between Human settlements and forests. The player is presented with a management exercise where she can promote development while balancing social, economic and ecological aspects in forest space. As part of an ethnographic analysis of our development praxis we synthesized a set of guidelines for the design of serious games, i.e. games with learning purposes, that have requirements of fidelity to the Body-of-Knowledge about the phenomena being modelled and learned.

Author Keywords
Learning games, game design, game-based learning

INTRODUCTION
The play activity is intrinsically connected to child development [5, 8]. As a form of play, videogames have occupied an ever increasing position in society in the last decades, in part propelled by a fast pace of technological advancement. As a result, videogames became an object of study in terms of their learning potential, as non-computer games before them.

Many authors, among them [7, 9, 15], have highlighted some characteristics that made videogames powerful contexts for learning, such as: to include different key elements of learning, to be engaging, to allow experimentation with and compare several perspectives, to support various types of representations, to be themed and provide contextualized learning. However, some studies that have tried to use videogames in a real context, especially using commercial-of-the-shelf (COTS) videogames, as with any other learning support or device, have to deal with challenges that can compromise the effectiveness of the learning outcomes. Challenges such as the adequateness of those videogames to the programmes being taught in schools or to the learning strategy being considered.

In order to overcome some of these challenges we attempted to contribute to the study of the design of videogames as learning contexts for serious use scenarios. In this paper we will describe the process of designing and implementing a learning game – "Living Forest" – for use in a science museum and, based on this experience, we suggest some guidelines useful for answering the problem of: "how to design a videogame with specific learning objectives?"

The main gameplay proposal of the Living Forest Game (LFG) is to administer geographical areas while experimenting with the possibilities and ecosystem interactions over 10 year cycles, throughout the course of generations. It is intended for the players to acquire sensibility for the possible actions and associated consequences over long periods, usually, beyond what would be their immediate life experience. The game action is simulated by considering the interaction between the player's management actions and their effects, over a geographical area modeled after a real setting. Multiple players share the same geography while managing different but interacting parts of the land, thus experiencing some effects associated with the concept of a shared ecosystem. Possible interactions are of two types: direct impact activities such as planting or cutting, or indirect activities such as agriculture, hunting and tourism. The goal of the game ends up being to find a balance between the different aspects – economic, social and environmental – that enables (and portrays an ideology of) sustainable development for the ecosystem.

Over the next section we present the background considered on this development case, then we proceed to describe the phases of the case development – research, design, implementation and evaluation, next we will introduce the purpose and context of use in the section "The Living Forest Game Experience". Later we analyze the design case and present a set of design guidelines formulated based on the ethnography of this experience.

Breaking New Ground: Innovation in Games, Play, Practice and Theory. Proceedings of DiGRA 2009

BACKGROUND

Games of simulation have long been addressed as learning vehicles part of educational strategies in Academia, Industry and the Military. On this line of research, Jan Klabbers summarizes and tries to structure an approach to the field in a recent compilation work in "The Magic Circle: Principles of Gaming and Simulation" [9]. Together with psychological studies of learning and games, the "games and simulation" community is probably the oldest and most established source of design knowledge for computer game studies in connection with learning.

As Klabbers states, through learning by doing it is expected that players gain knowledge about the subject related to the symbolic acts they perform during a game session. Motivation is pointed out as the driving force for the process of developing capabilities. The knowledge acquisition through the play activity is associated to different type of skills. Examples of these skills are to identify problems and solutions; to select, compare and differentiate relevant information from irrelevant information; and different types of thinking skills such as critical, creative and practical skills [18]. Regarding the performance of the players in the game, Klabbers identifies four types of interrelated sets of activities, which compose what he calls "The micro-cycle": actions and interactions, sense making and meaning construction, formation and adjustment of schemas, and adjusting the action repertoire. This concept of "micro-cycle" helps to model and understand the big picture of how the exploring occurs by the player during a game session.

Simulation games, as the case we present in this paper, stimulate visualization, experimentation and the creativity of the players [2, 7]. This type of games allows the performance of activities that otherwise would be impossible to realize or require too many resources [1]. The learning allowed by the experimentation of a game with a specific subject, form new relationships of knowledge and then prepare the players for future learning and problem solving in that, or related, subject. Moreover, the videogames allow the exploration of interpersonal relationships, encouraging attitudes of cooperation and competition within a strategic context, which may contribute to significant discussions after a game session.

Raph Koster, in his work "The Theory of Fun" [10], attributes to the learning practice a fundamental reason to the gameplay activity. If in a game everything is known or predictable, ending the process of learning, the interest in the game ends as the game becomes boring.

A significant number of commissioned reports by Foundations, public bodies and Industrial Associations are trying to promote awareness for the potential of games for learning, through what is being referred to as a "Serious Games" movement [12, 16, 17]. Many authors have focused on the learning potential of games, among them Gee [7], Prensky [15], Klabbers [9], pointed out the learning and cognitive development of gamers, demystifying the idea that games are simply addictive or alienating. Much to the contrary, research has shown that videogames can constitute mediators that operate on the subjects' Zone of Proximal Development – ZPD. For Vygotsky, the ZPD is characterized by the individual's need and opportunity to learn with the help of others, to realize activities that still can not do independently. Videogames by mediating languages (common and technical) play a fundamental role in this process [19].

The more recent "Games Studies" community, coming from a tradition generally rooted in Media and Humanistic studies has also made contributions to the public awareness of these subjects. In its PhD thesis, Egenfeldt-Nielsen specifically focuses on history related teaching with games in the school environment [4]. He used a commercial-of-the-shelf game with some success, and mapped a number of research challenges. Among them, the author exposes the problems of a) diverse gaming literacies of students and teachers, b) the lack of sufficient understanding for the role of games in the school learning process and c) the inability to reform learning activities to exploit the game experience to full potential.

In spite of the potential of games to be used as part of learning environments, cases that attempt to use games in real contexts, as the case mentioned above, have found some challenges that restrict the successful use of game in formals learning environments, especially in the use of-the-shelf commercial games. Our contribution is focused on the problem of special purpose design of a game to be played in a concrete exploration scenario, with specific, a priori, learning goals and fidelity restrictions.

THE "LIVING FOREST" CASE ETNOGRAPHY

Design Goals

The "Living Forest" game focuses on the management of humanized forest ecosystems, as opposed to wild forest scenarios, exploring the social and technical aspects involved. The purpose of this game is to allow an interactive experience to a playful exploration of the natural, social, human and technological dimensions, promoting player's development of a holistic perspective about the Human-Forest relationship. The game was commissioned as part of the interactive collection for a Science Museum dedicated to Forests, under what was termed a "Living Science" program supported by the Ministry of Science and Technology.

The central game design objective is to provide the player the experience of managing a geographical area, by the acquisition and management of concession areas, exploring possibilities of interactions in the ecosystem over generations. The central goal in gameplay is to maximize the credits resultant of a proper management of the areas administred by each player, finding a balance between the different aspects – economic, social and environmental – which enables the sustainable develop of an ecosystem. The simulated management of forest areas is subject to a realistic simulation model, based on the current Body of Scientific Knowledge in Forest Management: The game will encourage the search for a productive balance, penalizing the blind maximization of an isolated objective (e.g., wood extraction) without keeping in mind the feedback circuits, translated into landscape, social and environmental costs.

Some of the possible or transitory sub-goals or strategies in gameplay may be to maximize the managed area, to maximize the production of a specific product, to maximize the biodiversity or landscape value, to maximize the population density in a sustainable way or to manage the oldest balance.

Circulations were defined that include costs and benefits by industrial human activity, commerce and tourism, by the sustainability and development of population, and by preserving the biodiversity and impacts on the ecosystem. The game offers the player the possibility of managing stimuli on these phenomena in the form of taxes and budgeting, or by direct action, supporting the cost of implementing actions (e.g. planting, cleaning, cutting), getting its benefit and calculating side effects.

A balanced management allows the accumulation of credits and the expansion by the acquisition of new concessions. The idea set is that of a typical management game. In terms of gameplay experience, this kind of game values the perseverance in the face of challenge and the continued reflective activity, stimulating what stakeholders consider to be favorable attitudes, in a public who is intended to be captivated for a techno-scientific practice, or simply for a more ecologically and socially responsible behavior in their relationship with the forest.

Related competencies in Basic Education

Since there was an anticipation of use of the game in formal education, regarding the ludic experience that the game aimed to provide, we analyzed the National Curriculum of Basic Education [13] which sets general and specific competencies expected in each level of Basic Education (until 9th grade), in order to identify core competencies teached in school that could be related to and exercised by the game concept. Concerning the game subject, we analyzed disciplines such as "Physical and Natural Sciences". Examples of the selected competences that influenced the game design were:

- Recognition that the imbalances can lead up to the exhaustion of resources, the extinction of species and the destruction of the environment.
- Planning and implementation of action aiming the environmental protection, the heritage preservation and the balance between nature and society.
- Understanding that the ecosystems dynamics result from interdependence between living things, materials, and processes.

Domain Research

With theme and conceptual design defined, we started the research phase, which provided significant information to include in the game design. This phase also relied on the involvement of an expert in the scientific domain of forest management, a researcher at the Forests Department of a Polytechnic School.

Through documentation by the National Forest Inventory we gathered statistical information about the characteristics of Portuguese forests, such as the main existing species, the area they occupy, typical volumes, mass, density, growth, age distributions, etc of each species, the main bush types and other flora and relevant fauna to model the ecosystems. During this phase, some questions were raised as to the implications of this information for the game design, specifically how detailed the model should be, for instance, which species to include and which forest areas/geographies to consider. Beyond these questions, we begun to assemble a set of hypothetical player actions to model.

One important issue of the research phase was to understand the main roles performed by forests. With the help of the expert, we defined the roles such as production, protection, conservation of habitats, forest grazing and recreation. For each of these roles, we analyzed services and related products we could model in the game economy. We analyzed these products and services keeping in mind the geographical reference area for the game, in order to give it a stronger resemblance to a real localization, as opposed to a general abstract setting. Products included wood, extracts, flowers, mushrooms, honey and herbs, and direct services included tourism, hunting and fishing. The landscape characteristics of the reference area were also analyzed, in order to influence the design of the game world.

An important requirement in the game was the realistic simulation of forest growth. Therefore, we studied a methodology [6] to predict the volume, height and productions of various species. In spite of the complexity that this model presented, the study of this methodology enabled the team to understand what could be the variables and the requirements of a realistic yet simpler model. To study the growth of each species to include we used various documents [3, 11, 14], identifying variables such as the rate of growth, density and maximum age of growth. Together with the data about the simulation of forest growth, we investigated the production and economic value of the various products.

Game Design

From the original idea and based on the information collected during the domain research phase, decisions were taken regarding a simplified design for the game, we will describe next.

One of the first decisions concerned the role played by the player. We considered some possibilities similar to reality, such as the role of a manager in a forest management corporation or a city mayor. Nevertheless, the decision went towards an intentionally "abstract" role of an independent manager of pieces of a geographical region. This decision was due to do with the implications between the role of the player and the logic of the game, especially when it comes to the semantics and pragmatics of the actions and decisions that the player is called upon to make. The player's role is directly related to the subjective model adopted to develop the individual's holistic perspective of the relationship between Humans and Forests. So, some urban and rural areas, which have economic, social and environmental influences between each other, were defined by means of neighborhood interdependences. In the on-site installation there were to be three exploration consoles, therefore the design includes three urban areas characterized as villages. Each player is associated with one of these villages, having the opportunity to make decisions that directly affect the economic development depicted on that village. An influence of forest areas organized by single unit of management (each player) was defined to each of these villages, and the player has the possibility to individually undertake actions on each of those areas. The option of representing the forest areas as single areas is due to a simplification of the simulation model and to reuse of the experience that the players may have regarding this logic of interaction. A major factor on the definition of the number, size and location of the single areas was the approximation to reality and the possibility of what the player can explore in a limited time.

The Experience of Time

One of the major design challenges was to let the player experience the consequences of decades or centuries of decision making in a time frame between 15 minutes to one hour. Since the dynamics of forest management take an unusually long time between decisions and effects it is usual for people to loose a sense of consequence and miss-manage or ignore the opportunities to intervene, leaving private forests effectively abandoned and increasing risk of events such as fire. It was part of our goal to use the game to overcome this lack of sensitivity by enabling perception of long term forest related phenomena.

As such experiencing the anxiety of the passage of long "forest time" while enabling the fast paced decision making typically expected in a game became a challenge. In the game flow we decided that the game should be played in synchronous concurrent turns, and came up with a device of a virtual daylight period of 3 minutes by a 15 second night representing the passage of 10 years. Thru this device we intended to enhance the "cause/effect" perception of relationship throughout generations. At the end of the "night" marking each turn, the result of the effects caused by the actions of the player during "daylight" are updated. Considering the forest lifecycles which consume long periods of time, it was defined that on each turn of simulation, ten years would be a reasonable period, also related to the slow pace of intervention in the real context, from 5 to 5 years. The three minutes for each turn were based on a relation with the typical expected duration of an exploratory activity on the Museum during visitation. Usually restricted to fifteen minutes, it would be possible to experiment the videogame for several generations, enough to generate interest on the player to pursue it later on. Later, in order to allow the player a chance to get to know the game, it was decided that the first turn would have five minutes instead of three. With the same intent of adapting the videogame, so that the player would not have to start from an awkward deserted land there would be some plantations of advanced age in some areas.

Gameplay Actions

Of all the actions initially thought out, a simplification process led to include only: "claim an area", "abandon an area", "plant", "rough-hew", "cut", "clean", "invest" and "manage budget". The actions "claim area" and "abandon area" allow the player to choose the areas he intends to manage. For the action "plant", a selection of local species was considered: Oak, Arbutus-tree, Poplar, and Eucalyptus, Pine tree, Olive-tree and Cork-oak. These types of tree were chosen for being representative of the Portuguese landscape. Some procedure rules were associated with this action: a plantation can be configured by several species, even though it is only possible to "plant" on empty areas; there are some restrictions towards some of the species; it is not allowed to plant forest species in the areas near the villages, aside from "Olive trees", to prevent fires near the houses; because of the preservation of the water resources, it is not allowed to plant some of the species near river banks. The biodiversity, which contributes positively to attracting tourists, inhibiting the propagation of fires, and attracts fauna, is assessed by means of the heterogeneity of species planted.

The simulation of the growth of plantations is modeled in terms of the density recommended to each of the species, which can be reduced with age in some cases. The action of the game "to rough-hew" allows the player the possibility of controlling the density of each of the species planted. Still regarding the simulation of the growth of plantations, it was defined that the action "to cut" allows the player to cut down a species in a determined area. Even though these actions are available throughout the game, it was decided that these actions should be automatic due to the limited time available for exploring.

Along with the growth of the species, it was decided to also simulate weed and bush growth as they relate to conditions for apicultural exploration. Moreover, the weeds also contributes to an increased risk of fire propagation. To eliminate weeds and bushes increasing the thermic charge from an area, related to risk of fire, we defined the action "to clean"'.

For modeling the economic leveraging of the forest ecosystem, we defined game actions we called "investments". As an option of this action, the some investment types have been considered: sawing, distillery, oil extraction, beekeeping, plant nursery, fishery, inn keeping, camping and hunting parks. Each these investments was selected having into account its function in the game logic and representativeness in the holist perspective of the model. The investments sawing, distillery, oil extraction, and apiculture allow revaluing incomes of raw materials, by transforming them, while the existence of a plant nursery has implications in the cost of the plantations, reducing it. The investments in inn keeping, camping park and hunting parks contribute to increase tourism who visits the village.

In order to represent fire prevention and fighting measures without risking turning the game into a fire-fighting drill, the player can simply allocate an annual budget destined for forest maintenance, forest monitoring and fire–fighting means. There is also a budget for promotion. Values are deducted are deducted at the end of each turn. The fires are considered a main threat to the forest. For the simulation of fires, in each turn some higher risk areas may "catch fire" and some may get it by propagation, depending on species and population density, biodiversity, etc. Effectiveness of fire-fighting and propagation is affected by maintenance budget.

Indicators

As indicators of progression the player is given an employment rate, a tourist attraction index, resident population, and credit. The employment is a function of the direct work and investments, and current active population in the area. The tourist number is an abstract index of attractiveness, depends on promotion, biodiversity, and capacity of existing tourist investments and environmental quality. To assess the environmental quality, it was considered the difference between the estimated value of the carbon dioxide resultant of the investments and the population, and the estimated value of carbon dioxide consumed by forests. The number of inhabitants is a function of employment, economic returns and environmental quality. The number of inhabitants is indicative of the development of the village.

Issues of Representation and Interaction

Implementation of representations for the game scene was the task demanding more resources of all the development. Along with the research phase, began conception of how the game scene would be represented, specifically with the production of concept art. Some drawings were made portraying possible elements that would come to be part of the game scene, as, for example, recognizable representations of the different forest species, some characters, typical rural landscape buildings and fauna.

In order to visually represent the concept being modeled in the game logic, several elements were elaborated to compose the game scene, 3D models and textures were created for trees, characters, animals, buildings, communication means, animations such as planting, lumbering, hunting, etc, and effect such as fires, water streams, rivers, etc. Sound composition relied mostly on reuse since the team did not include a specialist. Sounds revealed fauna and human activity, e.g. the sounds of children near the village signal happiness and growth.

In the game interface, a perspective of a flight over the field of the game was chosen, which is typical in this kind of games. The player can move the camera over the geographical area of the game and zoom on specific areas to get a detailed view. The landscape is characterized by hills and valleys, with game areas explicitly marked. We opted for defining the positions of villages, forest areas, water passages, ways, roads and bridges, in view of an approach to the real scenario. The animations of vehicles circulating in the roads or birds flying in the sky also indicate activity.

The passage of time is visually represented in the game through variable daylight illumination imitating the passage of a day. The player carries through the chores during the "day" and the ticket of the turn occurs during the "night". For each of these periods, day and night, there is associated ambient sound, such as, the singing of a rooster at dawn, the singing of birds and the humming of bees during the day, and the singing of owls during the night. Together with animations sound is mostly used for ambiance, to enhance the sense of place.

While conceiving the representation of villages, we tried to include the typical characteristics of local rural villages, either by the elements chosen to characterize it, or by the physiognomy of those same elements. First, the streets were drawn choosing a typical stone pavement. Throughout the streets, houses, public poles of illumination and public buildings, such as a bandstand, churches and schools, were positioned. The village's development, calculated by the number of inhabitants, is depicted visually by the number of houses and layout, having the village, in the beginning of the game, a limited number of houses. Investments are represented near villages to which they are associated. For each investment type, there are models, textures or animations which represented associated Human activity.

For the identification of the areas under player management we opted for an explicit placement of landmarks and flags to signal belonging. The management of an area is represented by the rank of a flag in the area, with the colour associated with the respective player. Through the modification of the texture, the flags also have the function of catching the player's attention, e.g., when one determined species reaches the age of cut or must be roughed-hew. Gameplay actions such as "to plant" are animated for feedback. The model and the texture of each species portray the physical characteristics of the species, as the height and the visual aspect. The growth of the plantations is represented by the increase of size of the respective models of each species. In this case, special attention is paid to the maintaining coherence between the size of the model of each species and its rhythm of growth in height. The visual diversity of the existing species in the areas should also be indicative of landscape appreciation for that that region. The design of interface components, or overlays, evolved with the gameplay model and evaluations on the prototype: a zone of pointers, a panel with game indicators, a message board, a map, timer and a toolbar or action area.

Implementation

The various tasks of the development process of the game "Living Forest" were made by a multidisciplinary team of ten people. Game production involved game design, concept art, developing of 3D artistic components, programming and playtesting. The game was implemented in a rapid prototyping platform for multiplayer online games which made it possible to reach demo stage in 4 months.

The development process was done in four iterations that included implementation and evaluation. In the first iteration a single player version of the game was implemented featuring a basic simulation model. Although it was testable, this version of the game had obvious needs for improvement, especially in terms of usability. The main aspects to improve were the interface aesthetics, the lack of feedback for some actions and game state. In the second iteration, in addition to the improvements identified previously, the logic of game was adjusted in order to become multiplayer. In the third iteration aesthetic improvements were included and this version was evaluated with the target audience in a school context. In the last version, simulation model was tuned and some optimizations were done.

Evaluation

During development several evaluation sessions were carried out. There were sessions with the stakeholders responsible for validating Museum contents, with the expert on forest management and with members of the target audience.

The evaluation with the stakeholders focused on assessing the adaptation of the game to the scenario of use. Thus, some recommendations were made in terms of usability, such as the adjusting of the zoom action to the physical device used in the final installation, a trackball, some suggested adjustments to accelerate the gameplay, e.g. by making some actions "automatic" and thus taking into account possible restrictions on the time to explore the game during visits.

The evaluation sessions with the expert focused on the validation of the simulation model and analysis of validity or adequateness of possible interpretations during the exploration of the game. From this evaluation, suggestions had been made for the refinement of some values for the simulation related to the calculation of the products and growth of species. In addition, some restrictions on cutting and plating in different species were proposed in order to turn the management scenario more realistic. A question of representation also came up regarding fidelity of how forests were being depicted and if that was consistent with age and density, e.g. if the player can see the ground with an adult population then something is wrong.

With the target audience we aimed to test the game in a scenario near to that of the Museum before actual installation. There were three players in each game session and a facilitator to guide the exploration of the game; students aged between twelve and fifteen years old with various levels of experience with computers and different types of games. The evaluation sessions took place in a school with thirty students of the 8th grade and the testing session resembled the final usage scenario, with duration of fifteen minutes. During these sessions, which were recorded on video for later analysis, the students had been asked to record their profile, played for a 15 minutes and were debriefed during the later phase of gameplay. Questions addressed the following aspects: to understand which actions are available; to understand how to perform the actions; to find and understand the help information; to perceive the progress in the game; to perceive events in the game; to perceive the position in the game world; to perceive the results in each round. Through the answers and the analysis of the play sessions, it was possible to conclude that the adopted interaction solutions appear to be satisfactory in general, but there were difficulties by some players to set the values for desired densities of each species and to consult the panel of results in the middle of a round.

Aiming to assess aspects related to the process of learning, a set of questions which had emerged during and after the experimentation of videogame, depending on the behavior of the players, were asked. With these questions we tried to identify the following aspects: agreement of actions being taken with the goal of the game; perception of the existing species and their potential; understanding of the products gotten with each species; understanding of the function of the investments; perception of the transformed products; understanding of the causes underlying the variation of the success indexes.

Varying results for each these aspects were achieved among the playtesting population. It became obvious that those with some gaming literacy managed to understand, with some easiness, the goal of the game and make interpretations of the game model to answer the questions regarding the tasks they had to undertake and its consequences. For those with less gaming literacy playtesting revealed that the period of experimentation was clearly not enough to go beyond a surface exploration of the interface.

During experimentation sessions at the Museum interaction between players was common, with commentaries on results and comparison of strategies and values. There is clearly an opportunity for a deeper evaluation of game use during more extended sessions of experimentation. Even so, it was possible to have a qualitative appreciation that more literate players were able to make interpretations of the gameplay convergent with the learning goals which were considered in the game design.

ANALISYS AND DESIGN GUIDELINES

This section presents some guidelines for serious games, synthesizing the learning from the development process described. The design process of this videogame was based on the following conjecture: if I learn to make decisions within the game world, then I can make comparable decisions in the real world. The game designer starts to conceive the game model and through the implementing it will lead to a system model. The player builds his mental model, through the interaction with the system model resulting in a gameplay experience and with enough experimentation, it is expected that the player's mental model will converge with the game model inscribed by the game designer.

The game model should be representative of the real phenomena.

To represent the real phenomenon means that the game model models that phenomenon, by including a selection of aspects that characterizes it, while excluding other secondary aspects.

The player builds a mental model of the game by interacting with a system implementing the game model. If the game model is not representative of the real phenomenon, the play experience will not contribute for the player to build a mental model consistent with the real phenomenon. In addition, to the possible impacts on learning, the representativeness of the real phenomenon may influence the engaging of some players, because the realism is one of the characteristics of games that capture player's attention.

In subsection "Game Design", we presented a set of decisions taken in the design of the "Living Forest" case in order to represent important aspects of the phenomenon of a shared ecosystem, economic (raw materials, products, investments), social (villages and population) and environmental (forest natural ecosystem).

The challenge in the game will be influenced by the complexity of the model.

The complexity of the game model is characterized by the set of parts that constitute the model and by the relations or interactions of those parts. The complexity of the game is necessary, and should be enough, to make the gameplay experience challenging. The higher the complexity of the game model, the likely higher will be the challenge to master that model. Mastering the game model means learning about the parts that constitute the model and their relationships. Thus, a game model should be designed with degree of complexity in mind, challenging enough to engage the players, without however becoming too obscure and lost in uninteresting details.

The game model should be balanced in view of the target audience and scenario of use.

The target audience and the scenario of use are factors that should be taken into consideration in the design and consequent adjustment of the game model. For target audience it is important to consider, for instance, the development stage of that audience and the gaming literacy. Regarding the scenario of use, it is important to consider such aspects related with the expected time for experimentation or if the exploration of the game will be guided or social.

The implications of these factors in the game model may lead to a redefinition of the available actions and their detail, or to an adjustment of the time allocated for gameplay events, as exemplified with the late balancing of the game model of "Living Forest" game.

The representations in the interface should be kept consistent with the simulated model and preferably all representations should have a purpose coherent with the interpretation of the game state.

Every representation constitutes part of the game interface, be it part of a 3D game scenario or the overlaid 2D GUI, and plays a role or interferes in the communication between the game and the player. Through the play experience, the player will interpret the meaning of the representations and then build her mental model about the gameplay. The representations should therefore be consistent with the game model and revealing of the game state, to enable the player to build a sense of understanding.

To prevent the player from building a mental model inconsistent with the game model, in a serious game all representations should have a clear and consistent purpose either in the interpretation of the game state or as an aesthetic contribution. The representations that have no purpose in the interpretation of the game state should be analyzed in order to assess the meaning that the player may draw from their interpretation. Here is an example of what a student said during an evaluation session, in which he interprets a misrepresentation in the behavior of the cars as an indicator of the stage of development of the village: "People don't want to go to the village, the cars get there and leave right away."

In this case, the interpretation made by the player is consistent with the representation, but since that representation was not tuned with the purpose of showing the stage of development of the village he gets the wrong idea.

The feedback to the player should be appropriate, guiding and significant.

In the design of the feedback in a learning game, feedback opportunity should be considered in terms of the timing it is presented to the player and of how the interpretations of that feedback helps the player building her mental model of the game. The feedback and its timing influences the dimensions that the player weighs in his mental model, while focusing the player's attention on specific objectives that the designer expects as part of the player's mental model and therefore incorporated into learning.

As an illustration, these issues are part of the reasons for the option to perform the simulation by rounds in the "Living Forest" case. At the end of each round feedback is given to all players on the long term results of the actions taken, expecting this feedback to influence the construction of their strategies and to help them decide on the next actions.

To strengthen the intentionality in the game, next actions should depend on the interpretation of the resulting feedback from the previous actions.

If the interpretation of the feedback resulting from the previous actions does not influence player's formulation of the following actions, it means that decisions may occur at random with similar interpretations and thus not rewarding reflection by the player. On the contrary, if the actions taken by the player build successfully on the interpretation of the feedback resulting from the previous actions, it means that the game will help the players evaluate their strategies, make decisions to strengthen these strategies of explore other options. These dependencies can directly contribute to the player's development of strategic skills as well as to the overall process of sense making, thus learning based on the game experience.

The actions modeled in the game should be significant in the modeled context.

The actions in a game are the expression of the player in the game. Together with the representations at the game interface, the actions modeled in the game are the opportunities for interaction that allow the players to explore the game model. To help the player to build from gameplay a mental model consistent with interpretations in the real world, the allowed actions should also be significant in the context being modeled, although simplifications. It was in this sense that we defined a simplified set of actions in the "Living Forest" game, on which a competence was also significant in the real world. From an initial set of actions, we eventually selected only those that expressed a greater meaning in the context being modeled.

The incorporation of learning goals in a serious game can be achieved by designing a context consisting of activities whose performance requires those knowledge goals to be met, while providing opportunities for the player to build that knowledge though gameplay .

Finally, we propose that learning objectives be incorporated in the game model in a way aligned with the performance objectives in the game. The activities that will allow players to achieve the game objectives should be idealized so that their performance results are directly influenced by the knowledge consistent with the learning objectives. Else, if the player's performance in the game does not depend of the building of knowledge consistent with the learning goals, it may be difficult to predict the result of the player's learning outcomes.

While in the design process of the "Living Forest" game, it was possible to examine how these aspects were taken into consideration. The key point of the central learning goal of the game – to find the balance between the economic, social, and environmental aspects of an ecosystem – is strongly aligned with selected skills, planning and implementing of actions aimed at domain learning, economic development, environmental protection, heritage preservation and balancing between nature and society.

CONCLUSION

In this paper we reviewed the general goals and approaches to serious our learning games and presented the ethnography of a design case for a simulation game designed to promote learning about Human and Forest relationships. Finally, design guidelines for serious games are presented as they relate to and are illustrated in experience drawn form the case presented. Further research will be required to understand the extent and manner in which the proposed guidelines are conducive to effective design results and the manner in which they should interact with aesthetic and other aspects of the gameplay experience.

ACKNOWLEDGEMENTS

This work was supported by the Fundação para a Ciência e a Tecnologia (FCT) (SFRH/BD/45114/2008).

REFERENCES

1. Berson, M.J. Effectiveness of computer technology in social studies: a review of the literature. Journal of Research on Computing in Education, 28(4), 1996.
2. Betz, J.A. "Computer games: increase learning in an interactive multidisciplinary environment". Journal of Educational Technology Systems, (24(2)), 1995.
3. Correia, A., and Oliveira, A. "Principais Espécies florestais com interesse para Portugal – Zonas de influência atlântica". Estudos e Informações nº 322. Direcção Geral das Florestas, 2003. (in Spanish)
4. Egenfeldt-Nielsen, S. "Beyond edutainment: Exploring the educational potential of computer games". Doctoral dissertation, ITUniversity of Copenhagen, 2005.
5. Elkonin, B. "Psicologia do jogo". São Paulo: Martins Fontes, 1998. (in Portuguese)
6. Falcão, A., and Marques, F. "Metodologia expedita para simulação do crescimento e produção de algumas espécies florestais portuguesas", Documento Técnico Nº 01/02, Grupo de Economia e Gestão de Recursos Naturais – ISA – UTA, 2002 (in Portuguese)
7. Gee, J.P. "What video games have to teach us about learning and literacy". New York: Palgrave Macmillan, 2003.
8. Huizinga, J. "Homo Ludens". Boston: Beacon Press, 1950.
9. Klabbers, J. H. G. "The Magic Circle: Principles of Gaming & Simulation". Sense Publishers, 2006.
10. Koster, R. "A Theory of Fun for Game Design". Paraglyph Press, 2005
11. Louro, G., and Marques, H., and Salinas, F. "Elementos de Apoio à Elaboração de Projectos Florestais", Estudos

e Informações nº 320. Direcção-Geral das Florestas, 2002. (in Portuguese)

12. McFarlane, A., and Sparrowhawk, A., and Heald, Y. "Report on the Educational Use of Games". TEEM (Teachers Evaluating Educational Multimedia). http://www.teem.org.uk/publications/teem_gamesined_full.pdf

13. Ministério da Educação. "Currículo Nacional do Ensino Básico – Competências Essenciais. Departamento da Educação Básica". Available at http://www.dgidc.min-edu.pt/fichdown/livrocompetencias/LivroCompetencias Essenciais.pdf (in Portuguese)

14. Polumin, O., "Árbores y Arbustos de Europa". Omega, 1999 (in Spanish)

15. Prensky, M. "Digital game-based learning". New York: McGraw-Hill, 2001.

16. Sandford, R., and Williamson, B. "Games and learning". Futurelab, 2005.

17. Savill-Smith, C., and Mitchell, "A. The use of computer and video games for learning – a review of the literature". Learning and Skills Development Agency, 2004. Available at www.lsda.org.uk/files/PDF/1529.pdf

18. Sternberg, R. J. "Abilities are forms of developing expertise". Educational Researcher, 27(3), 11-20, 1998.

19. Vygotsky, L. S. "Mind in Society: The Development of Higher Psychological Processes". Harvard University Press, 1980.