Environmental education through an online game about global environmental changes and their effects on coastal and marine ecosystems*

Natalia Pirani Ghilardi-Lopes; Juliana Cristina Braga; Simone Rodrigues de Freitas; Rosana Louro Ferreira Silva; Thaís Ribeiro; Erick Simões; Eduardo Pinhata
Center of Natural Sciences and Humanities
Federal University of ABC (UFABC)
Santo André, Brazil
natalia.lopes@ufabc.edu.br

Luciano Silva
Faculdade de Computação e Informática
Universidade Presbiteriana Mackenzie
São Paulo, Brazil
lucianosilva@mackenzie.br

***Abstract*—The scientific concept of "Global Climate Changes" is very difficult for most of the population, who tend to understand it as an abstract problem, distant in time and dislodged in space. Therefore, it is important to promote education based on the deepening of knowledge on the subject. The present study describes the idea and development of a digital educational interdisciplinary and systemic game on the influences of climate changes on marine and coastal environments. The game is aimed at students in junior high school and high school. The script, game design and level design documents are already finished. The scenario of the game is a coastal fictitious city called Apicum and the main character will have to understand the causes and effects of climate changes on the coastal and marine environments of the city. Throughout the levels, he/she will gain points of "Environment", "Society" and "Economy", the three pillars of sustainability.**

Keywords—science teaching, environmental education, educational games, marine and coastal environments, sustainability.

I. INTRODUCTION

According to the Environmental Education Department of the Brazilian Ministry of Environment, not only the government, but also all citizens are responsible for the change in posture regarding the environment aiming at minimizing and possibly reversing the anthropogenic influences related to global environmental changes, leading to the development of a low carbon society. This is a great challenge, since there is a clear distance between the comprehension of the global climate change phenomenon and people daily activities [1]. Constantly, news and information about these concepts are released by media, in schools and other communication spaces. In the period between 2005 and 2007, the 50 main Brazilian newspapers reported the question mainly under an environmental perspective (35.8%), followed by the economic one (19.7%), however they did not deepen the discussion and valued the impacts instead of the comprehension of causes and solutions to the problem [2]. Also, there is a distance between universities/research institutes and elementary/high school institutions. The knowledge generated by researchers is little accessible to school teachers and is not used in educational actions. In this context, Environmental Education (EE) can serve as a basis for a critical and transforming approach of the theme, making the intensification of civil society actions which alert the rulers of the world about their role in conducting this challenge possible in a near future.

In Brazil, the National Environmental Policy (Política Nacional de Meio Ambiente – PNMA) established the recommendation of the inclusion of Environmental Education in all educational levels [3]; the Federal Constitution [4], in the section VI of article 225, established the necessity of the promotion of Environmental Education in all educational levels and public awareness for environmental protection; the Environmental Education National Policy establishes EE and promotes the creation of state and municipal policies in much of the national territory [5]; and the National Program on Environmental Education (ProNEA) presents plans of action, principles and guidelines for several social actors and contexts [6].

Environmental education (EE) is characterized as permanent educational action in which the community becomes aware of his global reality, of the kind of relationships mankind establishes with nature, of the problems derived from this relations and their causes. Through this awareness, the learner can develop attitudes and values that hat enable behaviors aimed at the transformation of this reality [7].

II. RELATED WORK

Although there are several EE initiatives related to climate changes issue in Brazil, they do not establish a profound relationship between everyday actions and their synergies (transportation, excessive consumption, housing, food, land tenure processes, deforestation, silting of rivers, desertification etc..) with the increase of greenhouse gases emission [1]. Thus, environmental education programs and actions must be conceived in accessible language, compatible with different

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publics, in order to achieve effective population awareness about the causes and consequent impacts due to climate changes [8], and in consequence, promoting a systemic comprehension and a holistic and contextualized reflection on the complexity of the problem.

The scientific concept of Global Climate Changes is very difficult for the majority of the population and does not create an emotive bond with people. Therefore, there is a tendency to understand it as an abstract problem, distant in time and dislodged in space [1], even more when we consider the oceans and their biodiversity, also distant of the everyday of many people.

It is important, thus, to promote the teaching, in all learning spaces, based on the scientific deepening about the theme, for example, through the making of didactic interdisciplinary material with accumulated knowledge about climate and climate changes [9]. Silva et al. [10], for example, after applying questionnaires in order to survey teacher's and student's knowledge on the subject, developed a card game which helped them understand this environmental question and also discuss it in the classroom.

It is also necessary to print more transversality to the theme, almost always limited to the environmental bias, while Global Climate Changes (and its causes) possess inseparable interfaces with social, cultural, psychic and economical spheres [1].

This awareness and public engagement on behavior decarbonization involve three components: cognition (understanding, knowledge); affection (emotion, interest and concern) and behavior (action) [11]. The main EE actions challenge is the development of a language for the systemic thinking, which goes against what we normally do, that is, deconstructing things into smaller parts and analyze these parts separately [12].

Another aspect of EE challenges is the way to get public attention. There is a global tendency for one "knowledge society", in which internet, digital photography and cyberspace are radically altering the way that knowledge is constructed, represented and accessed in places outside schools [13]. Access to information if facilitated by technology and people become more and more active agents of the process of constructing their knowledge. Because of that, the use of information technologies in educational spaces is fundamental. Students of several ages play virtual games on a daily basis and are motivated when this tools are used at learning situations [14]. When adequately performed, through the use of reliable information sources, this kind of tool can result in a significant learning, in which the new information is anchored in relevant concepts already existent in the cognitive structure of the learner so that new concepts are built in with real meaning [15]. Following this tendency, the use of communication and information technologies is being highly encouraged and solicited in formal education [16, 17].

In this context, complex issues such as global climate changes and environment degradation can be better understood if accompanied by interactive learning strategies, which are related to the experiential learning of the students. Here we will put together both issues - global climate changes and environment degradation - using one term "global environmental changes". Experiential learning is divided in four phases [18]: concrete experience (internalization of experience through apprehension), reflexive observation (learning of concepts and abilities which enhance the performance of a person in known tasks within more or less defined contexts), abstract conceptualization (comprehension through interpretation, analysis and symbolic representation of concepts) and active experimentation (putting into practice the acquired knowledge). All these phases are equally indispensable when we think in education for low carbon societies.

Experiential and significant learning also encompass a strong emotional component. When the objective is not only to analyze, but also to promote changes, and when the changes are based in certain values, a certain level of emotional connection is essential, enabling the integration of apprehension with comprehension [12].

For this, educational games can constitute a powerful tool in this scientific information diffusion process, adapted to the general public and enabling the apprehension and comprehension of information, besides the direct and experiential interaction of the learner with the knowledge and, finally, the extension of all of this to a behavior change and promotion of actions that aim the improvement of socio-environmental quality. According to Gee [19] schools, workplaces, and families can use games and game technologies to enhance learning.

When playing, a person simulates and creates realities, with certain rules, roles, conditions and premises mutually accepted, and he can put himself in other shoes, developing an emotional understanding of why some people act in certain ways. Players learn "doing" and "making mistakes" without negative consequences to the real world, since some realities can be simulated, played, manipulated and experimented and the possible consequences can be felt. If consequences are negative, the player learns which NOT to do and can plan alternative approaches or objectives. Players can also share experiences, develop collaborative spirit and use the game for self-knowledge, understanding their attitudes, values and thinking processes better and also feeling and understanding the limitations and possibilities of promoting changes. Besides that, games are generally fun and pleasurable, increasing the emotional link of the player to the subject of the game.

Systemic games are a category of game with the objective of showing the players the functioning of complex systems. This kind of games is very interesting in the context of global environmental changes, which are the result of the interaction of several components of ecological systems. Systemic games allow for the player to see, feel and experiment several aspects of the system behavior, which is important if we want to encourage the transformation of the reality and the feeling of "being part of a bigger picture" [12].

III. A GAME ON GLOBAL ENVIRONMENTAL CHANGES AND THEIR EFFECTS ON MARINE AND COASTAL ENVIRONMENTS

This study aims at describing the idea and development of a game regarding global environmental changes and their effects on coastal and marine ecosystems.

A. The context and the story of the game

The scenario of the game is a coastal fictitious city called Apicum (Fig. 1). The story revolves around the fact that the city has been showing some strange circumstances. For example, the citizens are suffering with high intensities of raining and high temperatures. According to the main character's teacher, the local coastal ecosystems may be also suffering with these climatic anomalies and it would be important if the students comb about it. So, the main character of the story will have the task to investigate the causes of these climatic phenomena in the city and in the coral reef near the coast of Apicum as well.

B. The levels of the game

One important step in the development of a game is to produce the Game Design Document (GDD), which include the description the story, objectives, rules, all characters and items of the game, and the Level Design Document (LDD), which include the description of the scenarios, levels of the game, the conditions of entrance and exit of each level and the flow conditions in each level (what the main character can and cannot do). According to Kremers [20], although game design and level design are not in the same discipline, they clearly cannot exist without each other. Both documents are already finished for our game. In this study, the intention is to give an idea of the story of the game in each of the designed levels (Fig. 2).

In order to accomplish his/her tasks, the main character of the game will pass through nine levels, each one with well-defined educational objectives (Table 1).

1) Introduction level

In the introduction of the game, the character will be at a beach in a rainy day and he/she will have two options: 1) to the left he/she will see some ambulances in an area where there are illegal constructions which were damaged by an extreme storm and he/she will have to help some of this people to go to the ambulance and will also talk to a local dweller; 2) to the right he/she will meet some marine ecologists working on a rocky shore, they will talk about what is happening and the player will have the opportunity to help in the scientists research. One idea of this interaction with the scientists on the beach is to demystify the vision of the scientist as a "person who wears a lab coat and stays all the time inside a laboratory", which is very common amongst school students. After this two possibilities of interaction, the character will go to his home and there he will meet another character, which is called Caobimpará (which means "Blue sea" in tupi guarani) and will encourage the main character to know more about what is happening in the city and also in the coastal ecosystems, such as the coral reef. In this last part of the story interaction is not allowed.

After this introductory level, the player will be able to access the map of the city and the phases of the game which will be gradually unlocked. The first one is the "School" level.

2) School level – part 01

In this level, the teacher of the school will talk about global climate changes and the player will have to answer some questions in order to gain points. In the end of the level, the teacher asks for the students to go home and understand the amount of greenhouse gases they emit at home.

3) Main character's home level – part 01

In the level of the main "Character's home", he/she will calculate the greenhouse gases emissions and compare the result to the average Brazilian emissions (which is approximately 1.8 metric tons *per capita* per year). After that, the player will have to return to the school.

4) School level – part 02

In this second part of the school level, the teacher will talk about the greenhouse gases emissions and their consequences to the environment. Also, the player will learn about the marine and coastal ecosystems, interacting with the teacher when she asks about these subjects. In the end of this level, the teacher will ask the students to investigate a coastal ecosystem and the "Coral Reef" level will become unlocked.

5) Coral reef level

In the "Coral Reef" level, the player may talk to fishermen in order to ask for a ride to the coral reef. The fishermen will explain that it is necessary to know how to dive and to have diving equipment to go there. Also, they will tell that some scientists study the coral reef. In order to gain money to buy the diving equipment, the player may help the fishermen with their work. In the end of this level, the "Store" and "University" levels will be unlocked (the player may decide to each one he/she wants to go first).

6) Store level

In the "Store" level the player will be able to buy diving equipment. When returning to the coral reef, the player will be able to equip his avatar and dive. During the dive, he/she will meet Caobimpará again and they will talk about coral bleaching. The player will be able to take some environmental measures, but he/she will need to get some equipment in the university (if the player decided to go to the "University" level first, he/she may already have the equipment).

7) University level

In the "University" level, the player will talk to a scientist, formulate hypothesis and get some equipment in the "Laboratory" level.

8) Laboratory level

There, the player will have to find a thermometer, pHmeter, turbidimeter, oximeter, nutrient meter and one sampling unit. With the equipment at hand, the player will be able to take the environmental measurements in the coral reef.

Gee [21] argues that instructional games should include skills, knowledge, and values to allow the player to experience how members of a specific profession think, behave, and solve problems (authentic professionalism).

The objective here is to make the player learn about the scientific method steps (observation, hypothesis formulation,

experimentation, description and discussion of results and conclusion) in an intuitive way. Researches on education show that the students learn more about science and achieve better conceptual development when they participate in scientific investigations, similar to those which are performed in research laboratories.[22]. The idea is that the teacher use the game to propose problematizing questions to the students, aiming at developing the argumentation and discussion regarding their solution [23]. According to Azevedo [22], an activity can only be considered investigative if the student reflects, discusses and reports, which will give his/her work the content of a scientific research. Thus, an activity that has the investigative focus is far beyond providing only scientific knowledge, but also motivates students to pursue their learning about a subject, making it the subject of his own knowledge, learning strategies to think and solve problems, and one of the most important points, deconstructing the view of science as absolute truth [21]. So, we see the game as an opportunity to teach about the scientific method and its use in investigation of environmental problems, in accordance with the objectives of scientific literacy [24], which can be included in three structuring axis: (1) basic comprehension of fundamental scientific terms, knowledge and concepts; (2) comprehension of nature of science and the ethical and political factors that surround its practice and (3) understanding of the relationships among science, technology, society and environment.

Nowadays, in order to be competitive in the global economy, the Market needs to employ people that are able to "think for life". According to Alberts [25], some researches reveal that the private sector seeks employees that are capable of abstract and conceptual thinking, related to the real world complex problems – including problems that encompass the use of scientific and technological knowledge – which are full of ambiguities, non-standardized and with more than one correct answer. The author comments that more than listening to science and remembering facts, the students must learn how to think scientifically. This is one objective of our game.

With the environmental measurements at hand, the player must go back to the university and talk to the scientist again in order to reach possible conclusions. When talking to the scientist, the player will understand that the environmental questions are related to politics and the "City Hall" level is unlocked.

9) City Hall level

In the "City Hall" the player will be able to choose among candidates with different propositions regarding "Environment", "Society" and "Economy", and by doing this the player will get points on these three dimensions as well. Here, the goal is to show the students that there is a relation between our choices and what happens to the environment, society and economy and that we can plan what we want for our future.

10) School level – part 03

After that, the player must return to school in order to present his/her results to the teacher (all the points of the levels are summed up here).

The objectives of the levels are related to the development of abilities, attitudes and values regarding the "Environment", "Society" and "Economy", which are the pillars of sustainability. When completing the objectives, the player will gain points on these three dimensions. In the end, the player which is the most balanced among these three dimensions will be the most successful one.

11) Library level

Throughout all levels, there will be an unlocked level, which is the "Library" level, where the player will be able to get information for his/her research. In this level, the player will find information on: 1) ozone layer (since many students confuse the greenhouse effect with the hole in the ozone layer); 2) greenhouse effect and carbon cycle; 3) ways to mitigate global climate change - scientific information on ways to reduce emissions of greenhouse gases (including simple measures that can be taken at home); 4) basic information on the Brazilian ecosystems; 5) diving equipment – description and uses; 6) environmental factor measuring equipment – mainly those that the player will use in the story; 7) environmental legislation.

12) Main character's home level – part 02

After the end, the player will be able to access the "Character's home" level in order to minimize his/her greenhouse gases emissions.

Fig. 1. A game scenario. The coastal fictitious city of Apicum.

TABLE 1. Levels of the educational game on global climate changes and their effects on marine and coastal ecosystems, with the objectives proposed for each one.

Level	Objective(s)
Introduction	Help the people who suffered with an extreme storm Talk with marine ecologists
School	Learn about marine ecosystems and global climate changes
Character's home	Make his/her home more sustainable regarding greenhouse gases emissions
Coral reef	Visit a coral reef, measure environmental variables in order to understand why the corals are bleached
Store	Buy diving equipment
Library	Learn about the issues dealt within the game
University	Talk to a marine researcher and get help to understand the problem with the coral reef
Laboratory	Learn about equipment to measure environmental variables
City Hall	Choose for a candidate taking into account the three dimensions of sustainability

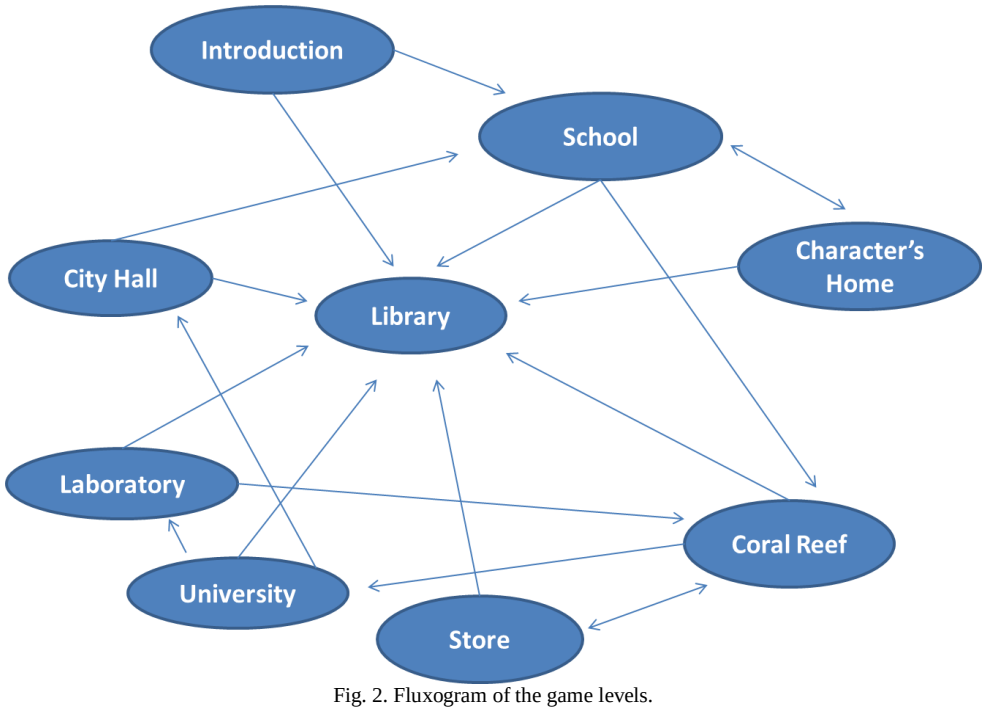

Fig. 2. Fluxogram of the game levels.

C. *The interdisciplinarity of the game*

Because the issue of the game is a complex one, the development team considered that it was important to make it clear that environmental questions are related to social and political ones. Also, the interdisciplinarity is explored in the game in different ways. For example, mathematics will be explored in the "Introduction" and "Character's home" levels; and physics, biology and chemistry will be explored in the "Coral Reef" level.

IV. CONCLUSIONS AND PERSPECTIVES

The game is still under development, but the script, game design and level design documents are already done. The objective is to produce a high quality educational material which can be used by elementary school teachers in order to make the teaching of the theme "global environmental changes" more attractive to the students.

The next steps include the implementation of the game, the preparation of a teacher's guide (since many teachers present some difficulties in using virtual learning objects) and the test of the game within schools. We consider that the evaluation is an important step after the complete development of the game. The process of evaluation should be the "engine" of teaching and learning process, in which professor and student will constantly verify and analyze the coherence of their explanations, the procedures and attitudes they take, in search for knowledge acquisition [26]. Also, according to Braga et al. [27], a good quality learning object (LO) must clearly explain its objectives to the user and it is really important that they are pedagogically evaluated before being available to reuse, which are the assumptions of the INTERA methodology. Generally, it is observed that LO contents lack desirable characteristics, especially with regard to the reuse and the didactic-pedagogic aspects. Many LO do not make clear to the teacher neither to the student the pedagogic objective to be achieved. This happens because these objects focus only in technical attributes and treat pedagogic attributes as marginal ones. This situation contributes to the low reusability of the object, since it does not aggregate value to the learning process, demotivating its use by teachers and students altogether. According to Mussoi et al. [28], it is possible to identify patterns related to the evaluation of assimilated knowledge through the use of LOs. In order to perform a systematic

analysis and an adequate evaluation of LOs, some criteria and aspects must be identified, such as the epistemological conception in which the LO is based on, the objectives which are described in its metadata, the quality of the addressed content, the ease of use by the student (and teacher), the interactivity and the used language.

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