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Design of an educational mobile game to foster critical thinking on environment pollution from the CTSA approach

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ABSTRACT

In this article, the main aspects of the design process of an educational 2d video game based on GameMaker will be developed. Its main purpose is to foster the curricular scientific alphabetization through the critical thinking. This educational game addresses the environmental pollution topic of "space debris" from the science, technology, society and environment (CTSA) approach. To this end, gamified settings focused on the stimulation and motivation are presented, throughout activities that incorporate real analyses of scientific data about the natural phenomena related to the external layers of the earth, and about the technological environmental consequences.

There is a lack of investigation and projects about educational mobile computing designing digital games to enhance learning based on critical, and scientific thinking, and that also allow an analysis of the data, phenomena and real issues. For that reason, some pedagogic guidelines and technical, graphic, and iconographic designs will be suggested to its development.

Author Keywords

Mobile educational games; Spatial contamination; CTSA approach; Critical thinking.

ACM Classification Keywords

K.3.1. [Computer Uses in Education]: Computer Uses in Education.

K.8.0 [Personal Computing]: General – games.

INTRODUCTION

Critical thinking is recognized today as one of the 21st century most important and influential skills, since it allows to act making conscious decisions based on reflection. According to many authors [3, 4, 5, 11, 13, 26], critical thinking is essential in the present world, and its relation with the scientific work is inherent, so much so that there are people who establish an uniform relation between critical thinking and scientific thinking [13], stating that critical thinking is the most important empowerment tool in the society, and science is, to a large extent, the practice of critical thinking, where lies its relevance to humanity [13]. From this perspective, critical thinking cannot exist without scientific thinking, and vice versa.

In Latin American contexts as in Chile, critical thinking is described institutionally as the ability of evaluate, reason, and make judgments with arguments to solve current issues [7], represented as one of the central axes to the modern society. Local investigations [12] have define the Chilean student population going to college with low levels of critical thinking development, representing a gap that does not allow to address the subject of learning quality with integrity. A necessity of improving the levels of scientific alphabetization from the critical-scientific thinking perspective is foreseen, especially in levels previous to college. In this point, however, it represents a pedagogic challenge, since involving students with the required reflection and deepening levels to generate critical thinking is not a trivial process. Mainly in the natural science area, where the studies raise that in Chile there are no real projects trying to create pedagogic strategies in a disciplinary area like physics [1] allowing to generate critical thinking abilities in the students. This situation may be addressed in different ways, and in this article, the first approaches to establish a strategy of articulation through mobile learning will be suggested.

PEDAGOGIC PERSPECTIVE

Mobile learning in science

Mobile learning can be seen as an experience and an opportunity given by the evolution of educational technologies [14, 24]. It is every moment and place where the instant learning occurs, the necessity of a customized world full of tools and resources that we prefer to create our own knowledge in order to satisfy our curiosity, collaborating with others and nurturing the experiences that would not be possible otherwise. Under this line, mobile learning in science context, especially in physics, will be a type of learning that will provide opportunities and experiences to thrive constructively and critically with the natural environment in order to seize the potentialities of the mobile technologies.

Studies have shown a link between mobile learning and the attitudes towards tasks and educational and formative practices [2, 6, 20, 21, 23]. In particular, there are researches about the mobile learning line in science that have highlighted a link in the curricular integration of mobile technology to enhance the pro-scientific vocations

[9], as long as it is well-founded on curricular pedagogical objectives. The aforementioned fundaments are stated to use the technologies as a booster and a partner to the cognition and as tools to improve the development, and the construction of deep and meaningful learnings, however, the practices using such tools as a booster must be justify in a necessity or in a learning problem [22], and under such statement, they require to be carefully design and implemented [22] under an active model that provide the construction and the contrast of meanings.

Curricular objetives

The progress of the design proposal is developed from the curricular integration [22] of the educational mobile game to reach mobile learnings, especially using smartphones. To develop the perspective of curricular integration in the Chilean context, the main referential and curricular document of Chile have been consulted: Bases Curriculares (BC) para la educación (2015) [15]. It should be noticed that the 21st century skills [19] are integrated in the BC (curricular bases). Particularly in natural science, the BC raise it structure from the great ideas of science: Grandes Ideas de la Ciencia (GIC) through the achievement of learning goals: Objetivos de Anprendizaje (OA). Thus, the work have started from GIC N°8: The earth composition as well as its atmosphere change through the time, having the necessary conditions to sustain life. From the OA of the thematic axis N° 16, on the first year of secondary education, it seeks to investigate and explain the astronomical research in Chile and the rest of the world, considering aspects like: the weather and the advantages of our country in the astronomical observation field. The technology used (telescopes, radio telescope and other astronomical devices). The contribution of Chilean scientists. At the same time, transversally, a level of main achievement OA of ability and scientific research processes: Habilidad y Procesos de Investigación Científica (HPIC) can be seen; observation and question formulation; plan and conduct a research, process and analyze evidence; evaluate and communicate.

CTSA Approach

A critical environmental approach at curricular level is the approach of science, technology, society and environment: Ciencia, Tecnología, Sociedad y Ambiente (CTSA), which characterizes the social aspects of the scientific-technologic phenomenon, trying to understand the conditionals as well as social and environmental consequences. Regarding this approach, different authors have theorized that the environmental approach allows to give a completer and more contextualized picture of science, and it suggests to consider the comprehension of environmental concerns and quality of life. Therefore, the CTSA approach seeks to establish a coherent conceptual framework with the bases on a sustainable future [9, 25]. This new attempt promotes reflections about the consequences generated by the technologies, environmental pollution being one of them as a current topic addressed globally. Proof of this is presented by the UN in the Sustainable Development Goals (SDGs) n° 13: take urgent actions to combat climate change and its effects. Particularly, the educational game focuses on the impact generated by the pollution of the external orbits of the earth (low earth orbit (LEO) between 180 and 2000km, intermediate circular orbit (MEO) between 2000, and 35780 km, and geostationary orbit (GEO) equal or higher to 35780 km.) where 100 million of units can be found in LEO with sizes between 1mm, and 1cm, 500000 units in MEO with sizes between 1, and 10cm, and 21000 units in GEO with sizes of 10 cm upward [16].

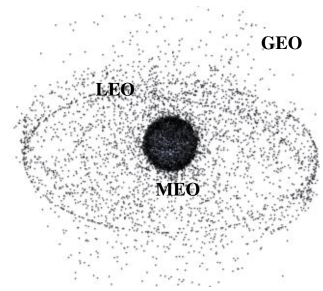

Figure 1. Density of debris by orbits.

Among the main characteristics of the space garbage is the damage generated when it collides with other objects present in the earth's orbit (satellites, space stations, airplanes, rockets, etc.), and when they impact on the earth's surface (crops, constructions, people, ecosystems, etc.). This implies that, in a long term, it will damage significantly the travels, and satellite, weather, and astronomic observations, generating a set of problems for the countries involved in that field, being Chile one of them.

TECHNICAL DESIGN OF THE EDUCATIONAL VIDEO GAME

To star off, it is necessary to clarify the concept of design to reduce the ambivalence that exists in its presentation, importance, and utility. Taking into account the visions around the concept of design, this will be considered as one of the basic characteristics of what it means to be a human being [10]. Under this line of thought, the design of the educational mobile game focuses on the basic needs of the daily reality, which are essential to the quality of life. Thus, by focusing every aspect of the design in the target user, each detail that is incorporated in the application is very important at many levels, potentially representing an enormous field of life [10].

Technical design

The structure design of the game stages has been developed focusing on curricular needs, constituted by 4 prototyped stages: menu design; level framework design, sub levels design, and complementary stage design. GameMaker Studio 2 was used to develop the prototypes, which uses the Game Maker Language (GML) to create scripts, events, rooms and instances. The sequence of the stages deployed are summarized in Figure 2. It describes a scheme of interaction between users, and the interface of the stages which are the bases of this educational game. It should also be mentioned that the start interface or “home screen” is the first stage of interaction.

Technical and pedagogical organization

In order to develop the specific curricular objectives, topics and activities have been proposed in the game to achieve these objectives. The dynamics of the pedagogic sequence start in the “topics menu”, when the user selects the first orbit “low earth’s orbit” to clean away the environmental pollution using a spaceship. The selection of the other orbits is locked until a given minimal percentage of cleaning is achieved in the previous layers. To achieve the required percentage in order to progress in the game, the user will need to develop activities in the “Activities Menu” in the following order:

1. To select the orbit level.
2. Before the game start, a screen of the educational material is used to display information about the effects of the environmental pollution.
3. When the user starts to play, there will be “specific goals” to achieve, like, clean up a specific amount of garbage (depending on the orbit the user is in), analyze the pressure changes, and temperature as the trip height increases, etc.
4. When the first level of the orbit is totally cleaned up, a quiz or a “level test” will pop up, with theoretical questions about the elements presented in the level, where the user should answer to get to the next level. If the user fails to accurately answer a certain amount of questions, the level will need to be completed again.

Graphic design principles

The graphic design process in GameMaker 2 has been complemented with the use of Adobe Photoshop CC 2019 to create the sprites. The decisions made on the design have been justified based on the design principles, from the perspective that says that the object being designed is not an isolated object, but a dynamic system, with historicity, that interacts, and give answers to the actions based on the interactions of its elements. Thus, we can talk about what the authors call an interactive system [17], in which the answers are processed before to react to the user’s actions. For this type of system, prominent authors in design works consider an emotional dimension [18] and stablish that certain principles are created to allow the utility and improve a fluid interaction. The principles considered to the interface design that is being proposed are the following: simplicity and clarity, feedback, user’s control, consistency and minimality of concepts, universal commands, view, and point, observe what is visible, and error consideration.

RESULTS AND DISCUSSIONS

Storyboard and interaction analytics

Based on the design principles, the home screen interface presented in Figure 3, highlights in yellow color two relevant options in order to make progress in the game: 1) “clean up layers” used to select the layer or orbit that will be clean from space debris, and 2) “played levels” used as a checkpoint of the last level played. At the top right corner of the start interface there are three icons with the same dimensions that represent: a help menu that deploys a screen with auxiliary instructions, a set up menu that allows the user to control variables of the game, and a profile menu to fill with personal information and to check the game achievements.

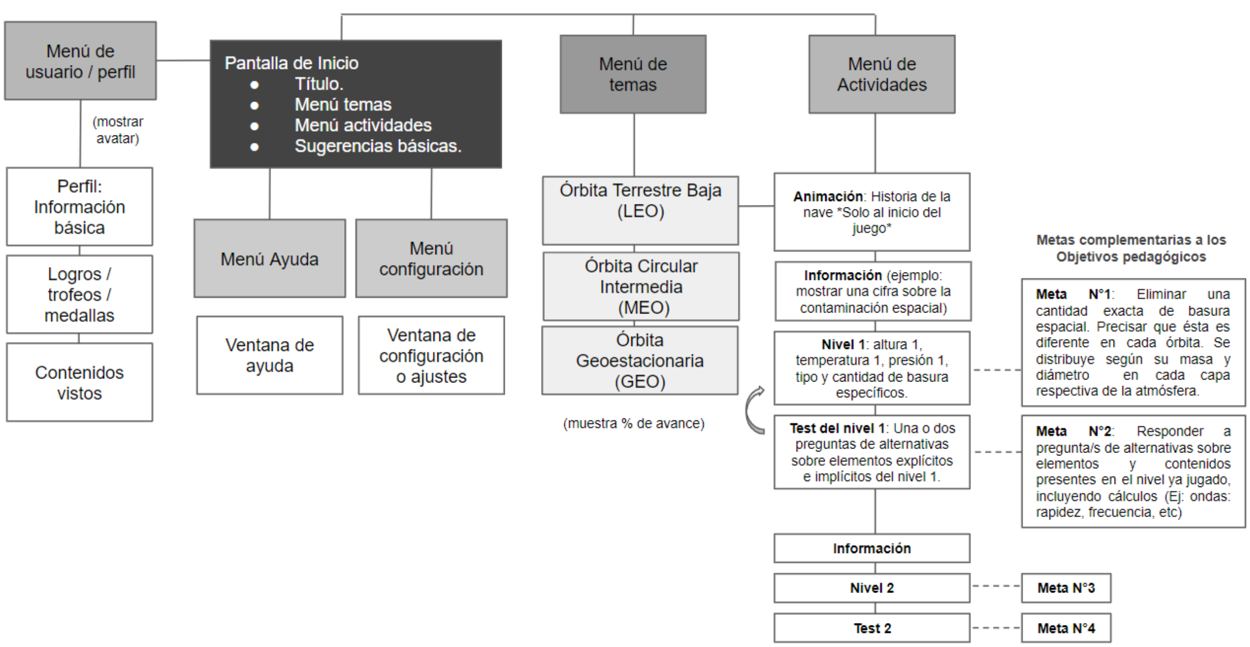

Figure 2. Summary of interaction between stages.

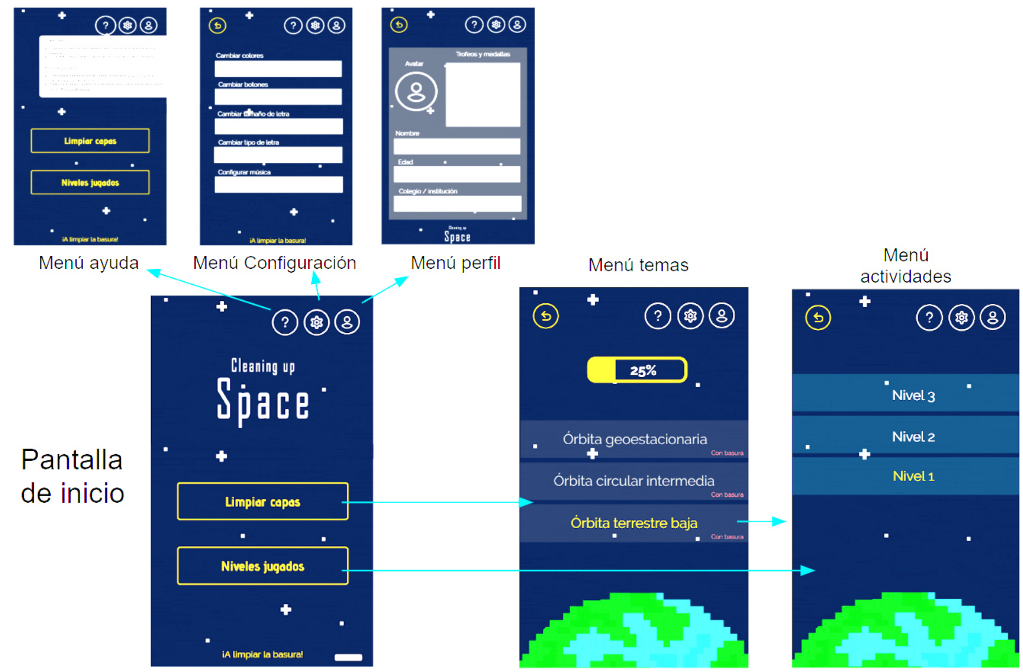

Figure 3. Graphical design of the home screen and the interface of topic and activity menus.

Finally, at the bottom of the screen there are recommendations about what to do in the game and how to do it. In the menu of topics, three orbits with the same size are presented to clean according to the progress percentage, which is represented by a horizontal bar in the upper right. An "available" green message allows to enter a stage, and a "locked" red message forbids it. In the activity menu, the levels of each stage with the same dimensions are presented. Both the topic menu, and the activity menu are presented in the upper-left corner, the back icon is represented as a yellow arrow with the same proportions as the other icons. Simultaneously, the sequence between the interface of the activity menu deployed by stages of information, levels, and evaluations is presented in Figure 4. In the analytics of interaction, the A tracking stands out: 1. the amount of shots, and its correspondence with the amount of garbage expected to be clean in each level, 2. The temperatures in degrees Celsius, the atmospheric pressure in ATM, and height in meters of each orbit, 3. The number of lives available, 4. The answers to the alternatives of the test about the information presented during the progress of the stage, and the coherence of the answers on the indicators of the pedagogic evaluation.

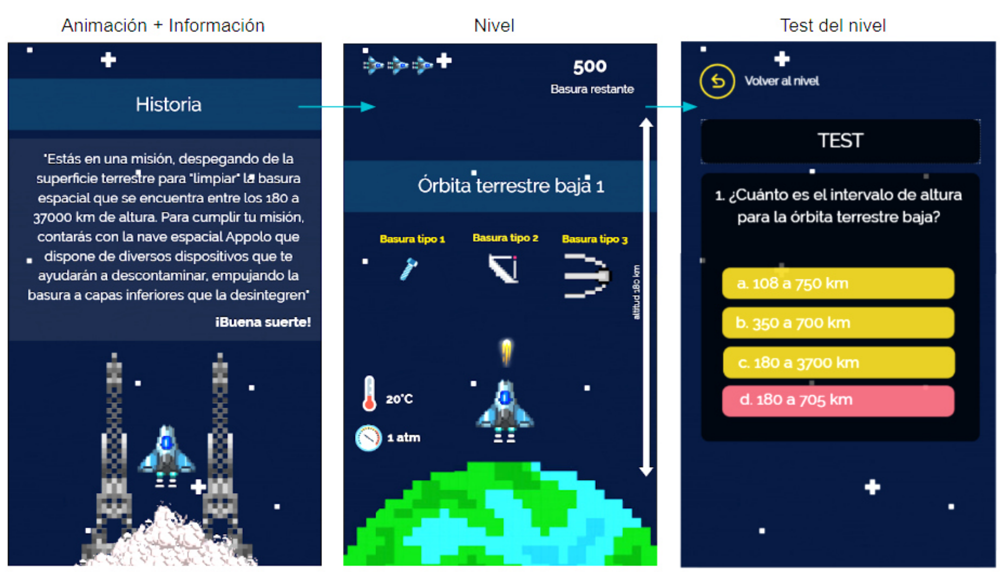

Figure 4. Graphical design of the sequence: activity menu, information, stages, and evaluation.

FINAL CONSIDERATIONS AND FUTURE WORKS

This research aims to foster the development of scientific skills that will help to acquire environmental critical thinking abilities regarding the space waste in schoolchildren. About this, and after a long revision of literature on the subject, theoretical, and practical models of technical design, and of curricular-pedagogic articulation have been suggested; along with the construction of the first functional prototypes via rooms, scripts, events, and instances that allow its development.

However, it is still necessary to continue with the research to carry out tests of usability with final users, that is to say, schoolchildren of secondary education in Chile. Then, analyze and verify the results of the effectiveness of the suggested model to perform the required adequations.

Throughout analytics, is expected to achieve a correspondence between the evaluation indicators established on curricular bases. Thus, the results of future evaluations of the educational game are expected to contribute with an objective input in respect of the specific dimensions of learning by means of the critical-scientific skills. Simultaneously, deeper analyses are required to characterize, describe, and correlate aspects of the motivation that foster the educational game, and its link with learnings.

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