

Mobile Serious Game Proposal for Environmental Awareness of Children

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Abstract— One of the many difficulties faced in cities include the accumulation of waste in streets, sidewalks, public squares, causing major environmental problems. This is not only due to lack of public policies and urban infrastructure, but also lack of citizen participation. Given this scenario, there is a crucial need to educate the people, especially children, who represent the future of society. This study presents a mobile serious game proposal, called “*Protecting the Earth*”, about selective waste collection, recycling, reduction of waste production and waste reuse in different game stages with focuses in childish public. The methodology adopted included Systematic Review; application of Participatory Design methods, such as the Context Inquiry technique; specification of functional and non-functional requirements and the study of technologies appropriate for developing the project. Experiments were conducted with children aiming to assess the proposed tool’s interface. The results obtained by means of usability testing with users showed the need for adjustments in the interface in order to achieve greater accessibility and user satisfaction, and were met immediately. The next step is to perform learning evaluation experiments in order to verify if the proposed serious game is collaborating to acquire user knowledge about the study object (Environmental Education).

Keywords—*serious game; environmentally sustainable; Three-Dimensional Virtual Learning Environment; Environmental Awareness of Children.*

I. INTRODUCTION

One of the many difficulties faced in cities include the accumulation of waste in the streets, sidewalks and public squares, causing major environmental problems. This is not only due to lack of public policies and urban infrastructure, but also lack of citizen participation.

Zikmund and Stanton [1] highlights that the bigger barrier is the citizen himself, that is used to the discard consumerism. Comber and Thieme [2] identified in their study that only the United Kingdom discarded 5.3 million

tons of food and 4.9 million tons of recyclable garbage per year, improperly.

Given this scenario, there is a crucial need to educate the public about questions related to organic and inorganic garbage discard, especially children, who represent the future of society. Environmental awareness measures could include: selective waste collection, recycling, reduction of waste production and reuse of waste. Although, these themes are introduced in schools in disciplines such as Biology and Science, generally isolated, an interdisciplinary approach since the first school years is necessary, in order to understand the problem in global levels in different society sectors.

Considering that environmental awareness, specially related to garbage reduction, reuse and recycling, can have positive global proportions, the environmental sustainability theme has been one of the fastest growing research fields in the computer science area, due to the area potential to offer Three-dimensional Virtual Environments (3D VEs) that can stimulate an environmentally sustainable behavior and ecologically aware the citizens [2]. Besides that, computational systems can add different interaction strategies that include learning based on games, virtual characters, virtual humans, collaborative environments, among others. In these Virtual Environments (VEs), the contents can assume funny, interactive ways and the VE interaction strategies can transform the learning in a more involving activity.

In this context, the conception of a Three-Dimensional Virtual Learning Environment (3D VLEs) based on games (serious games) can offer a ludic and interactive environmental education.

According to Alvarez and Djaouti [3], serious game can be defined as computer software, which has as proposal the combination of serious aspects of teaching, communication and/or change of information (serious) with the fun experience that a digital game offers (games). Serious Game has been a tendency in educational field in different knowledge areas [8], such as Medicine [10, 11], Mathematics [9], Biology [12], History [13], among others, because of awakening curiosity and motivation, at the same time it seeks to develop educative and sociocultural aspects in the users. Wrzesien, Lopez and Raya [4], highlighting that games uses from actions instead of explanations, rising the motivation and satisfaction of users in the learning process.

Methodologies concerning design and programming of serious games for mobile devices, promote the reach of environmental education in different contexts, ages, locations and socioeconomic backgrounds. Additionally, the greater knowledge of the young generation regarding the need of reducing waste, recycling, reeducating, and complying the “garbage in the garbage” rule, the greater awareness will be in the future societies.

Therefore, the aim of this study is to present the development of a mobile 3D VLE based on games (serious games) about selective waste collection, recycling, reduction of waste production and reuse of waste in different game stages with focuses in childish public. The serious game, called “*Protecting the Earth*”, is split in three stages with growing difficulty levels and explores the interdisciplinary among Science, Mathematics, Portuguese Language and Arts disciplines.

II. MATERIAL AND METHODS

Previously, we conducted a Systematic Review (SR) [5] in order to investigate which the main methodologies/techniques of Participatory Design (PD) are being applied in the 3D VE design process with educational focus to the childish public.

From PD techniques found in the literature, we select the Contextual Inquiry and Mockups techniques because they can be applied since the beginning of the interface project development. Therefore, the serious game interface project, to be presented on this work, was developed applying PD approaches.

Contextual Inquiry technique consists on field interviews conducted with the final users in their real work context and Mockup is a final prototype of the object to be developed, with the goal of testing, studying or sampling of its artifices [5].

This way, periodical brainstorming meetings and interviews were performed with the project stakeholders

(teachers, psychologists and therapists) and the development team. Additionally, it was included in the design process the participation of childish public through the Mockups technique, in order to evaluate the usability and accessibility of the proposed interfaces.

Highlighting that serious game proposed demands to contemplate the interdisciplinary of the curricular contents in 3D VE, as being one of the requirements requested by the project stakeholders.

Regarding to software developing model, we have chosen the incremental due to its flexibility, once the stages of specification, developing and validation are interleaved [6].

Highlighting that the serious game development is grounded in the Preliminary Reference Model for 3D VLEs for conception hospitalized children [7], which includes the non-functional requirements of the application, the human factors and interaction strategies considered relevant to the domain in question, but being possible to extend to general childish public.

The first version of the serious game was developed to Android Operational System¹. The Android platform offers a free developing kit, which allows the execution of the 3D VE in many different mobile devices that uses this kind of Operational System. In this way, the game can be widely used in various types of mobile devices (cell phones and tablets), becoming more accessible to the childish public diversity.

For the character modeling, we applied the Blender² tool. This tool helped on the modeling of characters, 3D objects and game scenarios, by having a wide resources palette, being compatible with many platforms and governed by a public license.

3D characters' animations were imported from Mixamo³. Mixamo Technology uses machine learning methods to automate the steps of the character animation process and has compatibility with other tools used in the game development, such as Blender and Unity.

In order to game environment implementation, we used the game engine Unity 5.3⁴, for being a complete game engine, intuitive and provided of a robust rendering engine, beyond offering a free developing version and a wide community of users. The programming language used is C#, due to its compatibility with Unity and a significant amount of tutorials for learning.

¹<https://developer.android.com/sdk/>

²<https://www.blender.org/>

³<https://www.mixamo.com/>

⁴<https://unity3d.com/company>

Serious game is split in three stages that will be introduced in section IV. The first version of the game includes the implementation of the first and second stage, which were validated by the project stakeholders and by potential users (children between 6 to 11 years). Third stage is been developing and consider the results obtained by the PD techniques applied with the project team.

III. SERIOUS GAME IN EDUCATION

Along the years, the use of serious game gained visibility in the academic field in different areas of knowledge, specially, by the association between entertainment and knowledge acquisition. According to Mitgutsch [14] “the combination of playing and learning based on digital technology has been identified as a major task of twenty-first century investigation on learning”.

When a person is playing, the learning becomes a challenge, since it is necessary to understand the game controls, objectives and rules; give meaning to the character’s stories; and explore the space provided by the game. At the same time, the player acquires information that needs to be memorized and her/him needs to solve problems when taking actions in the game [21]. This way of learning can stimulate different sorts of knowledge acquisition since the strategies used in the environment are favourable for cognitive development at different learning levels.

Although the literature shows many initiatives of serious game conception in the educational field, this section presents some educational applications of serious games in the areas of Engineering and Computer Science in order to show an overview about the theme.

Mitamura, Suzuki and Oohori [15] proposes an educational methodology based on the concept “Learning programming through gaming”, which includes the application of four different types of serious games with the purpose of helping in the teaching and learning process of programming logic and object-oriented programming concepts. As part of the research, the authors developed games that allow students to learn Java language.

The study concluded that it is possible to obtain a basic knowledge of programming while having fun through these games. Additionally the serious game provides a deeper understanding of the programing processes executed within the game [15].

In Computer Science area, we found another study about serious game. Greitzer, Kuchar and Huston [19] investigated cognitive principles for the efficiency of learning and how they can be applied in serious game. For this, the authors examined a series of serious game

called “CyberCIEGE”, which represents a virtual lab of online training about computer networks security inside an environment based on games (Figure 1).

CyberCIEGE allows the users spend virtual money to operate and defend their networks and see the consequences of their choices. The concepts taught in CyberCIEGE refers to safety, covering different aspects of a multilayer communication network, since physical security to software security. The users buy and set up work stations, servers, operational systems and network devices. The CyberCIEGE includes simple and complex scenarios, which are presented following a series of steps, which require the user to protect more and more the corporative patrimony against attacks [19].

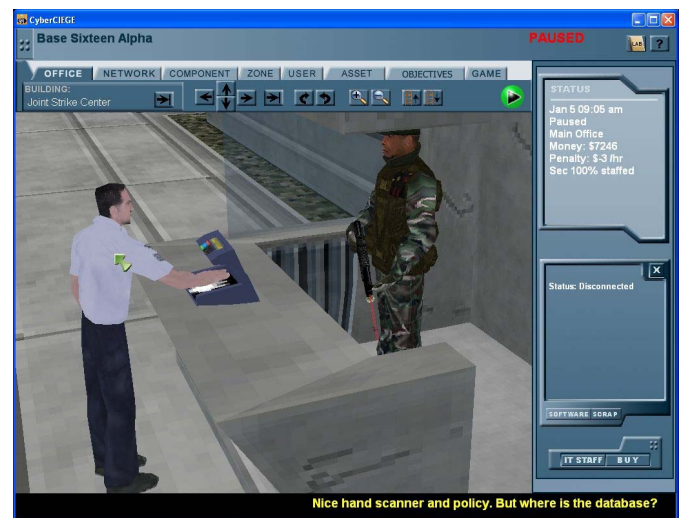


Fig. 1. CyberCIEGE serious game (example) [19]

Greitzer, Kuchar and Huston [19] did not evaluate the learning of users after exploring the game resources. Therefore, it is not known if CyberCIEGE contributes to raise the level of knowledge acquisition on users. However, some evaluations were conducted about the games usability and users’ expectations and satisfaction.

In the engineering area, we found the work from Birchall and Gatzidis [16] that present the development of a chemistry game, called Elemental, based around the periodic table of elements and atomic composition, deployed on the Xbox 360 platform. The serious game includes concepts of Chemical Engineering, Physics and Engineering, approaching atomic composition, protons, neutrons and electrons, size of the nucleus, amount of electrons layers, among others.

The progress in the Elemental stages is characterized by the periodic table progress, in other words, each new element consists in a new organization in the basic elements of an atom. Experiments were conducted with fifteen students and the results of the evaluation appear positive regarding the educational value of the game. In

the future, the authors want to explore the game using secondary school students.

Other research work with serious game in engineering area is presented by Callaghan et al. [17]. The authors discuss how virtual worlds and video games techniques can be used to create highly immersive and engaging environments for teaching engineering related material. The developed game counts with a range of 3D objects called “Sculped Prims”, which can be dimensioned, deformed and connected to form complex 3D models (Figure 2).

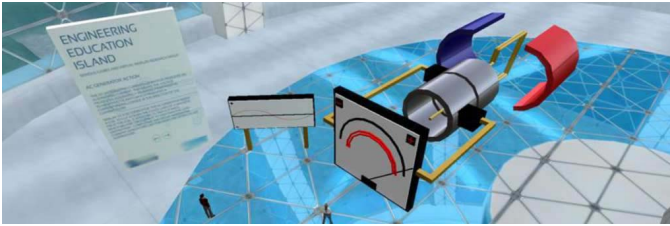


Fig. 2. AC generator demo inside the virtual engineering laboratory [17]

The 3D serious game successfully replaced the traditional 2D remote laboratory interface and showed that where appropriate 3D immersive environments could offer a new and engaging interactive way to teach engineering relate material [17].

Therefore, literature shows many research initiatives in serious game for virtual teaching and training, which highlights positive and negative points about its use in the educational field. However, it is a consensus in most of the identified studies, that serious games are pedagogical tools made to help learners develop specific skills, which can be seen as simulations of real-world events or processes designed to solve a problem [18]. Thus, it is up to the teacher using this powerful tool as part of the teaching methodology adopted in different areas of knowledge.

In sustainable development area, the literature presents few initiatives. A relevant work is presented by Chan [20], which proposed a serious game to stimulate learning in children about sustainability concepts such as energy conservation, deforestation and carbon footprints. The author interest is to investigate the potential of integrating constructionist learning principles with games. However, the game doesn't explore interaction and 3D modeling techniques.

We found some 2D and 3D game applications about taking care of the environment, approaching different aspects, but without evaluating the contribution of these games to the learning of related curricular contents, which is one of our projects' interests.

Considering this scenario, we sought to unite the digital technology, the sustainable development theme

and the curricular contents of the early school grades that approach classic concepts of caring about the environment (selective collect, recycling, reutilization and reduction of garbage production), in order to develop a mobile serious game, which besides being an interdisciplinary teaching tool, represents an important social impact and can extends in other themes in Environmental Engineering area.

IV. MOBILE SERIOUS GAME PROPOSAL

This section presents the main characteristics and stages of the mobile serious game, called “*Protecting the Earth*”. As quoted, this game searches to encourage the sustainable behavior and the environment preservation, as a way of reducing the environmental impacts caused by the lack of awareness from the citizen on the everyday life and by the bad consumption habits.

Considering that the main goal of the serious game is to educate and aware the childish public, the game starts in a kids' room. When the child turns on the tablet (Figure 3) he/she is invited to take care of the Earth through an interface that offers interaction, fantasy, competition, challenges and motivates the learning by means of interdisciplinary curricular contents [18].



Fig. 3. Initial interface of the “Protecting the Earth” serious game

In the serious games, the child can explore the virtual world through his/her customized avatar and interact with 3D objects that are available in the game scenario. Given the diversity of users (children) that will play the serious game, we projected avatars from different ethnicities (white, black and indigenous). This way, the game has six avatars, which are a boy and a girl for each ethnicity (Figure 4).



Fig. 4. Avatars for selection

The serious game “*Protecting the Earth*” is divided into three stages with increasing levels of difficulty and explores interdisciplinary subjects in Science, Mathematics, Geography and Art. Highlight that the game was developed only in Portuguese Language. The three stages are presented below:

A. First Stage: Recycling to Protect the Earth

In the game’s first stage, we approach the environment and recycling theme, presenting the types of garbage, the importance of selective collect and its contribution to the environment.

The first stage is proposed in a familiar place to the childish public, a square with toys, nature, fountain, birds, snack sale, popcorn etc. The square is called “Joy Square” (Figure 5). However, the game starts in a dirty square, full of garbage spread on the ground and even floating in the fountain water. The players’ task is to leave it clean, searching to protect the environment and learning curricular contents related to the theme.

The interdisciplinary of subject, cover Mathematics and Science contents, stimulate the environmental awareness and include risky situations to alert the children about the presence of “dangerous waste”. The Math discipline was included in the interdisciplinary because to progress in the game, the child needs, for example, in one of the game situations, to verify if the garbage bin still has space to throw the garbage in. Each garbage bin has capacity for 10 units of garbage and each kind of garbage has its own units.

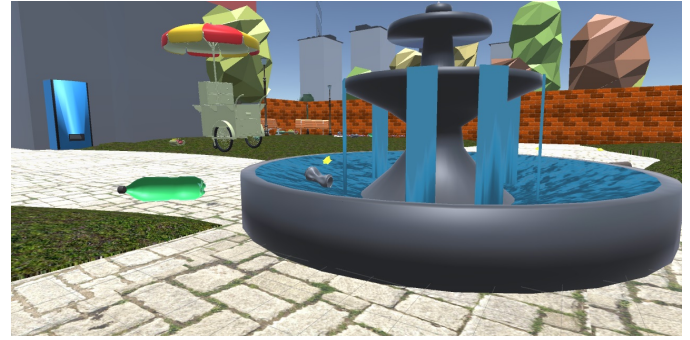


Fig. 5. Interface of “Joy Square”

The serious game has a stipulated time for the player to selectively collect the garbage found in the square. The player must collect the maximum possible of garbage and drag them to the right garbage bin, practicing the selective collect (Figure 6).

The scoring in the game is differentiated for the collect of garbage that takes longer to decompose in the environment, that means, these garbage types has greater weight of score.



Fig. 6. Interface with the garbage bin of the “Joy Square” to selective collect

When the player tries to catch a dangerous waste (syringes, medicine etc), an alert is triggered. In the case of dangerous waste, the child may request help from “Lady Rose”, the character responsible for assisting dangerous waste collection (Figure 7). Lady Rose executes the task to collect and put in the right garbage bin named “dangerous waste”.

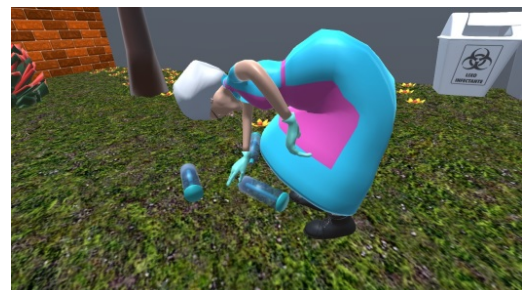


Fig. 7. Lady Rose collecting “dangerous waste”

The “*Protecting the Earth*” game, still presents the mascot “João Pinto” (Figure 8), a bird that acts as an intelligent agent with the aim of handing out tips that help the player make a decision. The game includes textual dialogues between the avatar and the game characters, which are represented by cartoons with facial expressions depending on the type of dialogue.



Fig. 8. Mascot “João Pinto”

This game stage was fully implemented and can be found available in the “*Protecting the Earth*” game.

B. *Playing of Reusing the Garbage from the Selective Collect*

The second game stage has like objective reusing the garbage from the selective collect to production of toys (Figure 9). This game stage explores the interdisciplinary through the curricular contents of Arts, Mathematics and Science disciplines.

The Arts discipline is present in the project because this game stage seeks to stimulate the children’s ability to create toys from garbage collected in the first stage, as showed in Figure 9. This practice is important, because what is garbage for some people can be art to educate others, as recyclable material. In the beginning of the stage, the player finds toys shadows that will be built from the reuse of the collected garbage.

The Mathematics discipline is approached in the geometric forms of the toys shadows. Therefore, the children need to identify, among the garbage collected in the first stage, those that are possible to fit in the geometric forms presented in the toy shadow, until forming it completely.

The Science discipline is represented in the garbage reuse, which is one of the ways of sustainability, together with the recycling approached in the first stage. This game stage stimulates a good practice of garbage reutilization in a ludic and interactive way.

The game stage starts with the maximum score, and the player loses points for each mistake done in the toy

formation until it gets the minimum score possible for the current activity.

The serious game considers as error, the selection of garbage that is not compatible with the geometric shapes presented in the toy shadow parts. This game stage is similar to a puzzle, which demands from the player the ability to identify the toy to be formed, the matching geometric shapes and the compatible garbage collected in the first stage.



Fig. 9. Production of toys – playing of reusing the garbage from the Selective Collect

This stage of the game was implemented and it is available in “*Protecting the Earth*” game.

C. *Practicing the Garbage Reduction*

The third game stage explores the interdisciplinary between the curricular contents of Geography and Science disciplines.

The Geography discipline is explored in this game stage because this phase seeks to stimulate the sense of orientation in the child through of a map of the house. This map will help in the route through the rooms that will form a labyrinth, guiding the spatial localization.

The Science discipline is represented in the reduction of waste, which is one of the ways of sustainability, together with recycling approached in the first game stage and the reutilization approached in the second stage. Together, they form the 3 R’s of the sustainable development.

Starting this stage, the player interacts with other characters with negative aspects in the game. Those characters have as function to waste energy and water, harming the environment. The role of the player is to act in a positive way, controlling the unnecessary consumption such as, turning off lights, closing taps, turning off electronic devices etc.

The scoring is given from a waste meter, which it represented by a bar that starts in the maximum level and continues gradually reducing while there’s a waste

ongoing in the house. The meter level reflects the player's score and his performance at caring with the environment. If the game ends off with the meter empty, it'll be shown an encouraging message asking him to work harder in the next time.

This game stage is under development. Therefore, we didn't conduct tests of this stage with users yet.

D. Limitations of serious game development

During the serious game development process, limitations related to the technology applied in the implementation were found. In the beginning of the development process, it was necessary to replace some 3D objects of the scenario, because such objects demand high processing power from mobile devices during the game execution.

Considering that the serious game project is foreseen to mobile platform, the processing power is limited, and one of the non-functional requirements is the game being accessible to devices with low processing capacity, in order to attend the diversity of users. This way, the development team has produced 3D objects for the game, in order to reduce the processing overcharge that can demand in reusing 3D objects available in three-dimensional libraries.

Other limitation found was related to animations techniques, which allow us to create animations according to the necessity of the scenarios in the proposed game. In general, the animations are pre-programmed, making it difficult to customize animations, according to the expected script for the game characters.

So far, we are using the animation package available in Mixamo Technology, which offers a catalog of animations ready and compatible with Blender and Unity. However, other techniques that allow us to customize the animations are being investigated.

E. Experiments

Experiments were conducted with 10 children (7 to 10 years) aiming to assess the proposed tool's interface and the operation of the first game stage. The results obtained by means of usability testing with users showed the need for adjustments in the interface in order to achieve greater user satisfaction, and were met immediately. To attend the ethical aspects of evaluation with users, the project was approved by the Ethic Committee from the Federal University of Mato Grosso, Brazil.

Some children show difficulty in identifying the garbage bin that they should throw some types of garbage, especially those that generated doubts related to the type of material used, such as:

- Candy wrapper – which material, paper or plastic?
- hot dog – shall we separate the packing from the organic when discarding the remains of food?
- medicine glass – is it a dangerous garbage
- rope – which material is it?
- hanger – it's not a common garbage in squares and could be made from metal and wood.

The volunteers that participated in the research suggested other garbage that could be found in a square, as popcorn, crumpled paper, bottle cap (metal and/or plastic) and newspaper. All suggestions were attended by the project team.

Highlighting that initially, the garbage bin named "dangerous waste", it was before calling "hazardous waste". This change was made due to the difficulty of four children that participated the test didn't recognize what is a hazardous waste.

When the child tries to get dangerous waste, the siren is played. However, during the tests, some children didn't realize the necessity to ask help for the adult character, "Lady Rose" in the case. So, it was included a dialogue box that is shown whenever the siren is played, in order to explain about dangerous waste and the necessity to ask help for Lady Rose.

Other experiments will be conducted with children of different profiles, limitations and contexts, in order to evaluate the accessibility of the "*Protecting the Earth*" serious game by specific evaluation methods.

V. CONCLUSIONS

In this paper we presented the "*Protecting Earth*" serious game and we hope that the game allows children to improve their knowledge about the theme. Regarding to the game development, it is possible to establish a contribution for the research community of the field of Games that develops Virtual Environments with educational purposes, as well as related areas that make use of 3D VE based on games for several objectives.

The research demonstrated that it is necessary to expand the studies about interaction techniques with no conventional devices, as the oculus rift, in order to improve the game immersion and associate them to the pedagogical aspects of the proposal.

We also observed that other animation techniques implemented in the Unity game engine itself need to be investigated, in order to reduce the processing costs and expand the types of animations in characters and 3D objects.

Although the serious game works in many mobile devices that use Android Operational System, the project team intends to expand the “*Protecting the Earth*” serious game to the IOS platform, in order to expand its public.

As for future research studies, other experiments with the “*Protecting Earth*” serious game in different contexts will be conducted, in order to verify if the proposed serious game is collaborating to user knowledge acquisition about the object of study (Environmental Education). New stages will be included in the game, seeking exploring other aspects of environmental awareness, such as sustainable energy and conscious of water use.

Finally, we believe that this study represents an important contribution to various fields of knowledge, especially in the context of smart cities considering Environmental Engineering and Computer Science.

ACKNOWLEDGMENT

This research was supported by the Institutional Program of Scholarships for Scientific Initiation of Federal University of Mato Grosso (UFMT-Brazil) and by the State of Mato Grosso Research Foundation (FAPEMAT-Brazil).

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