Treme-Treme 2.1 - Improving a Game for Children Awareness of Seismic Phenomena

Inês Batina
Instituto Superior Técnico

ACKNOWLEDGMENTS

I would like to thank all the people involved in this project, especially my advisors Professor Rui Prada and Professor Monica Ferreira for having guided and helped me during the development of this work. To Professor Marta Couto, and to the PhD Student in Education, Natalie Santos, who closely followed the process of developing the evaluation protocol, and also to Hugo O'Neill, the artist responsible for the entire aesthetic part of both the game and the website.

I would also like to thank all the schools that opened the doors for us to evaluate the game, EB1 Profª Aida Vieira in Carnide, Institute for Integrated Educational Development in Action in Tires and also to Prof Patrícia Gramaxo and her school, EB1 Arco Iris in Olivais.

Last, but not least, I cannot thank enough both to all my family, friends and colleagues for the support given over the last couple of years, and also to all the teachers at the Caneças School and in the Instituto Superior Técnico, who crossed my path and taught and trained me so that I could one day complete this stage of my life. To all, thank you very much.

ABSTRACT

Children are usually the age group most affected by natural disasters. Therefore, it is extremely important to educate them about what they need to do in case of danger to protect themselves. To achieve this goal, Treme-Treme was born. Treme-Treme is a serious game that aims to educate school children about how to behave before, during, and after an earthquake and/or tsunami. The game was first developed in 2014 and in early 2018, some changes were needed, not only to keep up with the new web and mobile technologies but also to improve some of the existing features. However, this restructuring has not been completed, and so this work follows on from that. In addition to completing the restructuring of the game, this work also resulted in a remote performance monitoring mechanism that provides researchers/project managers information about the game and the player, both the game and the player, both nationally and internationally.

Keywords

Earthquake; Tsunami; Serious Game; Children; Catastrophes; Game-Based Learning

INTRODUCTION

In situations like natural catastrophes, children are much more vulnerable than adults, therefore it is essential to alert and educate them about the dangers of these situations. In addition, they are much more available and open to learning this type of content than adults [10], playing an important role in the transmission of knowledge.

To address the concern that prevention is the best option, the work reported in this document was used to develop an improved version of the Treme-Treme[1], a game that aims to teach the knowledge necessary to prepare a child for an earthquake and/or tsunami. This document describes the steps necessary to conduct for the development of the game and all the tools that were created to collect data on the performance of the game and the player.

Motivation

In Portugal, this game has been used by several schools as educational support material, such as the exhibition *When Lisbon Trembles. From 1755 to Resilient City* at Palácio Pimenta in 2015, *European Researchers Night* in 2016 and 2020, and *Avante Festival* in 2018 [2]. However, the game was no longer updated and for this reason, began in 2019 a restructuring that needs to be completed. This restructure makes sense since multiple works in literature [3, 4, 12, 16] indicates that an excellent way to educate children is to leverage educational games. Authors like Shaffer, Squire, Halverson, and Gee, even claim that a new era of learning is emerging and that serious games are part of this evolution [13].

Context

Following the idea that a game is a good way to teach, and the idea that prevention is the best solution, in 2014 was born Treme-Treme, a serious earthquake and tsunami awareness game [1, 2]. This project was started by a partnership between the Department of Computer Science and Engineering (DIE) and the Department of Civil Engineering (DCE) from Instituto Superior Técnico, under the European project Urban Disaster Prevention Strategies Using Macroseismic Fields and Fault Sources (UPStrat-MAFA), and had the goal of teaching, in the context of the classroom, children with ages between seven and nine years old on how to act before, during, and after the occurrence of an earthquake or/and tsunami.

Objective

Between 2018 and 2019 the game suffered several changes and was migrated to a new platform, Godot[2], capable of exporting to both web and mobile platforms.

At that time, Duarte Botelho, despite making some changes and adding new elements to the game, only managed to complete the first two levels. So the game stopped providing the tsunami and the post-earthquake levels, being an objective of

[1] www.treme-treme.pt

[2] `https://www.godotengine.org`

this work to **migrate these levels to Godot and correct some problems that were identified** either in the current or previous version

This update (i.e., the migration and the correction of the identified problems) is necessary for the game to achieve its principal intended – *teaching while playing*.

Contributions

This new version of the game was already used in many events like Explica-me como se tivesse 5 anos, European Researchers Night and A Terra Treme. Besides that, the game is daily used for an average of 53 players in various parts of the world. This way we can teach kids on how they should act in earthquake/tsunami situations.

BACKGROUND

This section describes some concepts that are important to help to situate the reader on the theme and in the techniques currently used in similar situations.

Serious Games

In the universe of games, there is a wide range of games that aim to entertain and amuse the most diverse types of players. Within this range of options, there is one type that encompasses all types of educational games, serious games. In this genre, entertainment is not a goal, it is only integrated to help to transmit knowledge. More precisely, a serious game is defined as a game designed to facilitate the transmission of any type of educational content to the user and can span any type of age group depending on their goals [5].

Games in Education

The development of serious games is based on the theoretical foundation of constructive learning theories, where many articles in the literature showing that knowledge is created through experience while exploring the world and performing activities [7, 11, 19]. Experimental learning is advocated by a number of renowned psychologists like Lewin, Dewey, and Piaget, who denounce the way people transform experiences into learning [17, 19].

Gee et. al [8] described in his work some of the characteristics in games that contribute to the learning of those who are playing against them with standardized education. For the author, a game has the advantage of being able to provide feedback as situations occur, which is not possible with a didactic book.

Other authors believe that games provide the player a type of frustration that leads them to repeat the game until reaching the goal. This frustration is considered highly motivating as long as it is controlled. These games encourage the player to think about the future consequences that their actions will have, developing a strategic thinking [15].

Serious Game Development Theories

One of the main challenges of a serious game is to reconcile fun and education since the brain maximizes the apprehension of content when it is fun [20]. To achieve a balance between fun and learning there are a few factors to keep in mind in order to maximize the experience:

	High difficulty	**Low difficulty**
Low skills	Anxiety	Apathy
High skills	Flow	Relaxation

Table 1. Balance that must exist between difficulty and skills in order to achieve *flow*..

- **Game difficulty:** During the development of a serious game, we must constantly take into consideration that the essential is that the game motivates the player to continue playing. If the game has a very low difficulty the player will pass all the elements without acquiring any knowledge, as the game does not require much concentration to overcome the challenges. On the other hand, if the game has a high difficulty, the fun factor will diminish over time and the frustration will increase. This may lead the player to leave the game and, as with the low difficulty game, it will not acquire the knowledge that the game intends to transmit, making the game useless. According to the book *Encyclopedia of Adolescence* [18], the player can fit into one of the four quadrants of the Table 1 depending on the difficulty-skill balance. The aim of the game developers is to keep the player always in the *flow*, the state where concentration and learning are maximized.

- **Entertainment and Fun:** The main purpose of this type of games is to transmit knowledge to the player, but it is very important not to overlook the fun. Very dense narrative, a high number of multiple-choice questions, and dense blocks of text are practices that should be avoided as they lead the child to exhaustion. It is important for the student to be entertained while performing the tasks, not only to capture their attention but also to maximize the transmitted knowledge. To do this we need to combine the learning techniques, with a combination of design, story, rewards/achievements, conflict, and other elements of the game, that could make the experience more fun.

- **Feedback:** In a serious game, good feedback can be the difference between the child learning what is supposed, and not learning at all. The good feedback should be continuous, accurate and with a combination of audio and text (or only textual), as shown in the study by Goldberg et al. [9], but never provided only as audio, because it results in significantly lower mental demand.

- **Progression:** From the instant that we ensure that the *flow* state is reached, it is essential to talk about progression as players can progress to increasingly difficult levels as at each level the player acquires skills. Each level, therefore, has to have better and distinct skills.

In a book published in 1990, Csikszentmihalyi [6] reveals that during the *flow* state, when self-awareness is lost, we can achieve a state of fusion with the game environment, an expansion of personal boundaries, a feeling that fits the definition of immersion. Shernoff [14] goes further and suggests that there is a direct relationship between the challenge and the immersion that the game incurs into the player (i.e., the bigger the challenge, the greater the immersion).

Figure 1. Disaster Master is a serious game from *ready.gov* that aims to teach children to survive various types of catastrophes. This figure depicts a question that appears in the Tsunami level.

RELATED WORK

The area of game-based learning has been growing in recent years, however, the area of earthquakes and tsunamis is little addressed. This happens, perhaps because they are sporadic events that do not fit into the most common areas of classroom studies. In this section, we will look at some examples of games that exist in the area of earthquakes and tsunamis.

Disaster Master

Disaster Master[3] is a serious game that tells the story of four young people in various scenarios facing the most varied disasters. This game aims to teach children ages six to eleven to survive various types of hazards including earthquakes and tsunamis. The design of this game resembles a comic book in which the player must help the characters survive disasters. For this, a series of multiple-choice questions, are inserted throughout the story, defining the next step (as represented in Figure 1).

Build a Kit

[3] `https://bit.ly/37IEVTz`

Figure 2. Natural Disaster Survival is an online game where the objective is to survive as many catastrophes as possible, until reaching the top of the ranking.

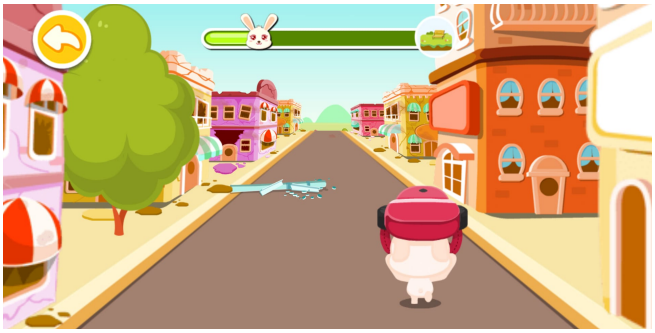

Figure 3. Little Panda Earthquake Safety is a game where the character has to be prepared to overcome the many challenges that an earthquake entails.

Build a Kit[4] is a game from the same collection as the Disaster Master, that teaches the child how to build various survival kits for several kinds of disaster. This game features a set of five levels where at each level the player is in a different scenario where they have to prepare an emergency kit. At most levels, the objects to be collected are not indispensable for survival in the event of a catastrophe, and many are unnecessary. At the end of the five levels, we are left with a final kit with about thirty-eight items making it impractical to carry in a backpack during an escape.

Natural Disaster Survival

Natural Disaster Survival[5] is an online game in which the goal of each player is to survive natural events. Initially, players wait for everyone in the room before being transported to an island. As soon as they enter the island, players have time to explore the island until the (randomly chosen) catastrophe is announced. After the warning has been given, all players must seek a safe place. When the catastrophe ends, all survivors return to the waiting room and a new scenario is generated and a new catastrophe will occur (see Figure 2).

Little Panda Earthquake Safety

Little Panda Earthquake Safety[6] is a didactic earthquake learning game for children ages three to eight that closely resembles Treme-Treme.

Unlike the other games already presented, this one was developed for mobile and starts with a little panda who has to build an emergency prevention kit. The game contains various levels where the character has to face earthquakes in multiple environments by choosing the best places to protect. After earthquakes occur, the small panda should be kept safe and fed using its emergency kit until help arrives. At the end of each level, a set of four multiple-choice questions are presented to consolidate the contents covered in the level, as depicted in Figure 3.

Tanah: The Tsunami and Earthquake Fighter

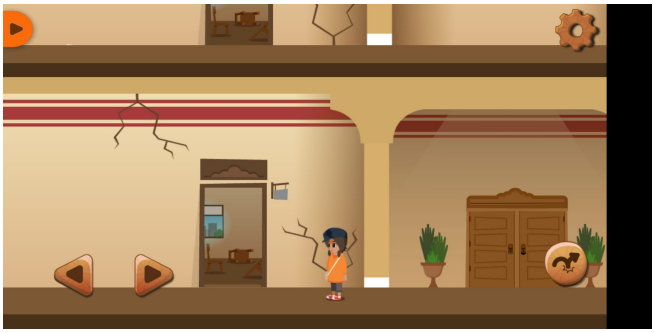

Figure 4. Tanah, an Opendream mobile game, where the character has to complete several missions to escape from an earthquake.

Tanah[7] is a young woman living in a place where earthquakes occur frequently, thus she has to be well prepared for these events. This game focuses heavily on prevention and the measures that must be taken before a catastrophe occurs (i.e., such as attaching cabinets to the wall). During the game, the player is faced with multiple-choice questions when crossing with another character, and the levels will end after the player completes all missions.

Although the game has a phase during an earthquake, it is so short and only covers a few challenges of that stage. There is also a phase during a tsunami where the goal of the player is simply to run while being chased by a giant wave, not teaching what should be done in such cases (see Figure 4).

Overview

Looking at all the games we saw in this Section, it is noticeable from Table 2 that the topic of earthquakes is starting to get more covered, but that tsunamis are still a short-addressed subject in the games that are currently available for children. Another aspect to note from the table is that none of these games focuses on all the phases of the earthquake and tsunami.

Treme-Treme presenting a game that conciliates all stages that both earthquakes and tsunamis have while maintaining the fun and maximizing the learning of the player.

THE GAME

[4] `https://bit.ly/3gmxG7S`
[5] `https://bit.ly/37IF3Cx`
[6] `https://bit.ly/2Yj2SvK`
[7] `https://bit.ly/2PdiSLC`

Game	Before	During	After	Earthquake	Tsunami
Disaster Master	No	Yes	Yes	Yes	Yes
Build a Kit	Yes	No	No	No	No
Natural Disaster Survival	No	Yes	No	Yes	Yes
Little Panda Earthquake Safety	Yes	Yes	Yes	Yes	No
Tanah: The Tsunami and Earthquake Fighter	Yes	Yes	Yes	Yes	Yes

Table 2. Summary of the phases of the earthquake that each game presents.

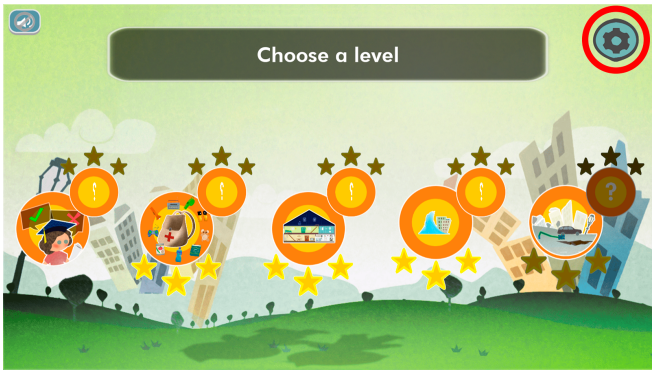

Figure 5. Main menu and game menu from the current version.

Treme-Treme is an single-player serious game that combines fun with learning, with a very important role in educating basic school children in case of earthquakes and tsunamis.

Game Changes

The first step was to understand what was missing in the game, as previously described, this project is a continuation of the work started in 2019 by Duarte and as such, there is a list of future work that he left for anyone to continue his work.

In addition to this list of tasks, it was necessary to understand what problems existed in the 2019 version. For this, a demonstration of the game was held at the school Profª Aida Vieira in Carnide, where twenty students aged between seven and eleven years old participated. In this demonstration, the students played the game until the end. While the children were playing, it was possible to observe which parts they had more difficulty with and where the loss of the *flow* state was noticeable.

Levels Menu

The menu of levels that was implemented, did not show the chronological sequence between the levels, which broke the coherence of the story that the game tells and, in addition, there was still the problem that it was not clear that each quiz was about one specific level.

To solve the problem of history coherence, the level icons were placed on a central line, which simulates a kind of chronological frieze of events, which evolves from left to right, so the story will begin to be told in the first circle and will end at the last. The questionnaires were placed together at the levels to which they belonged, but outside the line of the levels, as they are not mandatory and do not belong to the history (i.e., they are extra levels that the player may or may not complete, see Figure 5).

Settings and Pause Menus

The pause and settings menus of this game showed some flaws with respect to Nielsen's ten heuristics that describe the principles of interface design.

The solution was to redo the menus by correcting the flaws where the buttons were all placed in the same location on

the screen, the settings menus on the first and second screens became the same and the option of changing the language became available in both menus. The option to mute the game left the menus and became a button in the upper right corner (again following the examples of the games on the market) so that its access is quick and direct.

A button, that did not exist, was also added in order to be possible to reset the game.

Emergency Kit and House Mission

Duarte Botelho's [2] version was developed in *GLES3*, however, in his thesis, Duarte stated that *GLES3* could not be supported by older hardware [2], in addition to Safari and Edge not working, as well as iOS, as browsers are based on WebKit (i.e., Safari). Godot intends to remove *GLES3*, for that reason, in its documentation, Godot announces that the use of WebGL2 is not recommended due to its expected removal without replacement[8]. All of this led to the abandonment of *GLES3* to start using *GLES2*.

With the change from *GLES3* to *GLES2*, some features already implemented at the level of the Emergency Kit and that of the House Mission stopped working and had to be redone using tools that *GLES2* supports.

Expand the Game with New Levels

This section will describe the more technical stages of the game development process, that were necessary for the creation of the new levels and the consequent expansion of the game.

Tsunami Mission

The idealization of a tsunami level had already been carried out in 2014 by Pedro Barreto and at the time there was a working prototype that was not integrated into the restructuring of the game last year. For this, the first step that was taken to start the process was to recreate that scenario.

After the aesthetic part of the game was finished, only the implementation was missing and for that, it was necessary to rewrite all the code in GDScript. Note that some elements used at this level, were common to the House Mission level, and for that reason, they will not be described in this document but can be consulted at [2]

Character

Most of the functionalities related to the player, such as the ability to walk, have been reused. However, since at the home level the player just has to walk and lower himself, in this level (i.e., the tsunami level), he has to walk and use the items in the emergency kit. Thus, an animation of the character and respective audios were created for each of the items of the emergency kit.

Emergency Kit

The emergency kit is a container of items that the player has to choose at the first level of the game to use in the last two levels. To display the menu of the items in the Tsunami and Night Missions levels, a 2×3 grid was created containing six buttons corresponding to the six items. Each of these buttons sends a signal when clicked which then causes a change in the state of the game.

[8] `https://bit.ly/3kqEmCn`

The Wave

The tsunami consists of three animated sprites that are triggered when the player passes through the collider that triggers the wave. At that moment, a timer is started and two seconds later the wave starts going towards the beach. On the beach, there are characters that adorn the scenery that were animated sprites in order to behave serenely while the wave is not triggered, and to act in a chaotic way, fleeing and screaming, after the wave begins to appear. Each character and object present on the beach has a collider so that when they collide with the wave they are dragged by it. Two colliders were also placed that act as a floor and ceiling so that the characters do not fall or they are not projected to outside the game by the impact. In case the player collides with the wave he loses and the level starts again.

Night Mission

Similar to the previous level, the first stage of development was the creation of the scenario. This level is a circuit of obstacles that the player must overcome. That is why holes, the lead to the character to death when it collides with them, and buildings or posts, that fall when the player approaches, were added in the middle of the level.

In regards to the emergency kit, items that had no functionality in the previous level, like batteries and the flashlight, are now useful. When the flashlight is used, the player needs to change its batteries in the middle of the game since was to placed a collider that when collided emits a signal that informs that the batteries of the lantern are over.

When the player finishes this level the game ends, and to celebrate the victory of the player, a particle system that simulates fireworks is launched.

Increase the Number of Questions per Level

With the increase in the number of levels, it was necessary to create two more questionnaire levels, and during the development of the questionnaires, it was realized that the file that should contain all the sentences of the game was not complete and it was then necessary to complete it. A total of ninety-seven sentences were added in each of the five languages of the game. Taking advantage of the fact that the document would have to be revised by a linguist again, we take the opportunity to add more questions to each of the five questionnaires. In this way, the list of available questions per questionnaire increased from three to six.

Load Game

After the first development phase was completed, the game was exported to the various platforms in order to start the first testing phase. However, the executable files for the web were too large (more than 100MB), due to the many images and audio clips that the game has. So, when placed on the website the page loaded the game all at once, see Figure 6 (I), taking a long time to load (more than two minutes).

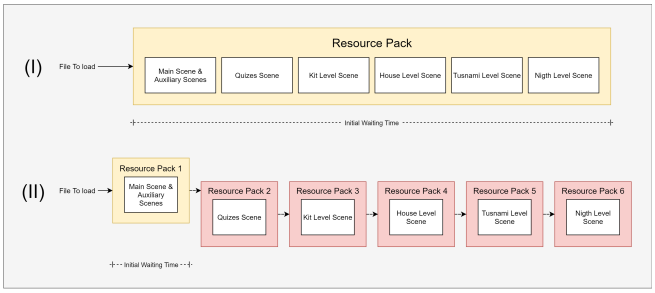

Figure 6. Scheme that demonstrates the difference between loading the entire data packet (I) versus loading in smaller blocks (II).

In order to be able to start the testing phase while this problem was resolved, was integrating a small mini-game at the time of loading to entertain the player while he waits for the game to start.

Background Music

During the execution of the game, the music jammed during the transition between scenes which led the player to abandon the game, thinking that the game had blocked. What happened was that the loading of the scenes came into conflict with the reproduction of the music, making a noise similar to what happens when the game freezes, since the system handled both events in the same process.

The solution found was to load the scenes during compilation and not at runtime. This alternative will overload the game load a little more, but it was the best alternative found under the circumstances of not being able to use multi-threading in the web version.

GAME MONITORING

This section describes a capture data system that was developed to help the investigators to measure the reachability and usability of the game, find some bugs, and measure the performance of the players. Even though this system is useful in many situations, emerged at the sequence of the online study that we had to execute. The developed tooling captures real-time data from the player, registering all the actions of the player. With this system, it is possible to see how many people play the game each day and even know if the same player comes back to the game days later.

Player Identification

The identification (ID) of the player is a very important step in any monitoring system since it is necessary to differentiate the players in order to be possible to follow their trail. For this was used a system of cookies that registers a random number unique for each player.

This ID allows that even on computers connected to the same network they have their own identifier, however, two players who play on the same computer and in the same browser will be seen as a single user.

Data Capture

The data capture process was initially designed to track possible bugs that could occur during the execution of the game.

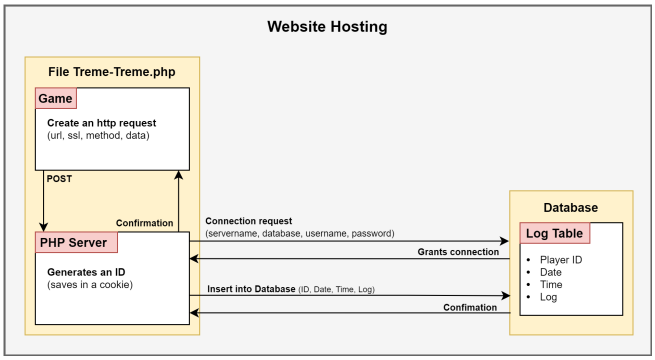

Figure 7. Scheme that summarizes the operation of the data exchange system between the website and the database.

The mechanism was quite simple and consisted of creating a text file (i.e., a log) using the Godot log capture settings. This log kept the error messages that occurred throughout the game, dumping the content to a file saved in the file manager of Hostinger.

The difficulty in obtaining information about the development of the test led to the need to change the data capture system. This change needed to provide, in online tests, the same data that we intended to observe in face-to-face tests. That said, the sending of messages became to be carried out via HTTP requests, and the storage is no longer done through files and is instead relies on a table in the database.

The implemented solution collects, at runtime, at all levels, several logs, being possible to monitor, evaluate and improve the performance of both the game and the player, since there is a specifiable sequence for the completion of each level, with more or less variance, so it is possible to perceive any iteration in the expected timeline that may be associated with a bug or some phase that is too difficult or too easy.

HTTP Request - Server Side

Whenever a relevant event happens, a message is sent, through an HTTP request to the PHP server, which is running the game. Then the server connects to the database and waits for POST (HTTP) requests.

Every time a request is received is sent to the database that records the time and day the message was received (see diagram presented in Figure 7).

HTTP Request - User Side

Whenever an event (that is considered interesting for analysis) happens an HTTPRequest node, that is placed in the scene tree, is created. This node receives the message to be sent in a string format and then converts it into a JSON format in order to be sent.

After the message is processed, the HTTP request is performed to the server URL, receiving as an argument the content of the message and, the HTTP POST method identifier that is used to send content to the specified resource. As soon as the response from the server arrives, a signal is sent indicating the end of the transfer, and the connection is terminated.

Data Representation

After all the data is captured, it is stored in a database, which makes it hard for people with no knowledge in the area to be able to access the collected information. In order to simplify this process of accessing the data, a private web page protected with a username and password (so that it is only accessed by the people in charge of the project) has been developed, providing the representation of the data in a simplified and easily accessible way. Through the web page, it is possible to monitor the history of any player each day.

With the information available in these tables, it is possible to obtain various statistics both on the performance of the players and on the retention of the game, as the number of deaths that occurred in each place where it is possible to lose, within each of the two levels. This information can be sawed on the page in the summary of the level.

Website Access Statistics

Treme-Treme is a game that was designed to be integrated into classrooms as a tool to raise awareness in the study of catastrophes. In order not to lose track of the number of the users of the game, the website of the game had a very simple visit counter that only increased if there was a view. That counter presented some problems, for instance:

- If a visitor navigated between the pages of the website, through the page menu a new visit was counted;
- If the same visitor accessed the site several times in a short period of time all accesses were counted;
- It did not allow to know which devices/browsers were accessed from;
- Did not allow the elaboration of statistics such as the retention rate of the site, the average time of interaction among others;

The solution arranged to solve all the problems involved the use of Google Analytics, a free service from Google. This alternative generates a script to capture visitor statistics. However, Google Analytics does not allow us to choose the initial value of the capture, causing the count to start from zero, thus losing the past history and does not display the number of visitors to the site. Although this is not a big problem, in this project this aspect was important for us that the visit counter was visible on the website.

In order to solve the problem of having to start counting from zero again and the fact that there is no counter on the page, the final solution emerged, consisting of a composition of the hypotheses previously described. This solution maintains the account in Google Analytics to consult the statistics, but with regard to the accountant present on the site, a script was developed in PHP that counts visits and presents them on the site as in the first hypothesis presented, but with user validation over ID over a period of time (see Figure 8).

EVALUATION

Initially, as already mentioned throughout this document, the assessment would be carried out in person, in two or three schools as initially planned. However, with the development of the pandemic caused by SARS-CoV-2 responsible, among other things, for the closure of all schools that took all children home with online education between March and September 2020. This event meant that the tests that were expected to be carried out in schools had to be adapted and carried out remotely.

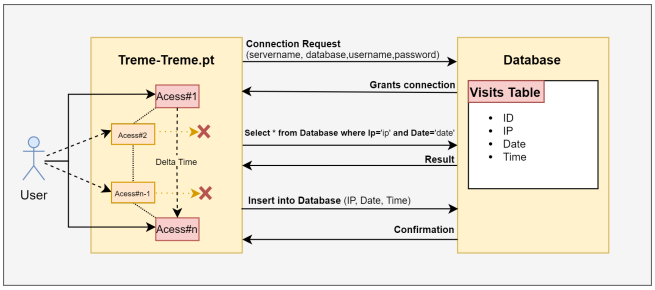

Figure 8. Example diagram of how the access count script works.

EVALUATION

Initially, the assessment would be carried out in person, in two or three schools as initially planned. However, the development of the pandemic caused by SARS-CoV-2 responsible, among other things, for the closure of all schools that took all children home with online education between March and September. This event meant that the tests that were expected to be carried out in schools had to be adapted and carried out remotely.

Online Evaluation

The first evaluation that was carried out had the objective of testing the first ready version of the game and was carried out with two classes, one from the first and the other from the third year of schooling that counted with twenty-seven students in total, with ages between six and eight years old. This evaluation had as main objectives:

- Detect possible bugs that could exist;
- Test the performance of the game on different machines;
- Test the immersion of the players;

The link to the game was made available as a daily task in google classroom so that all students had access and at the end, they would have to answer a gameplay questionnaire slightly adapted to the age of the children. The final questionnaire totaled ten questions about gameplay and eventual bugs that may have happened. The selected questions can be consulted on the Table 3.

Assuming that, if all the factors assessed in the questionnaire are reached by the majority of the players, we can believe that the state of *flow* is being reached in the majority of respondents. To see this, we calculated the Cronbach's alpha can be seen in Table 4 where is verified that the α-value was 0.797 which is larger than 0.7 and, for this, we can process the result together. So a T-Student hypothesis test was performed with a level of significance of 5%. To verify if the hypothesis that assumes that if the average of the answers of

	Questions
i	What do you think of the game you played?
ii	Was it easy or difficult to play Treme-Treme?
iii	Were you focused on the game while you were playing?
iv	Did you think time passed faster while you were playing?
v	Did you feel like playing again when the game was over?
vi	Did you feel you were the character?
vii	Did you feel you were living a story?
viii	What level did you like the most?
ix	Did you have a problem playing the game (ex: crashed)?
x	If you could change something in the game what would it be?

Table 3. Questions list of the gameplay questionnaire.

Scale	i	ii	iii	iv	v	vi	vii
1	0	1	0	3	4	8	5
2	4	8	3	2	0	1	6
3	1	2	1	10	8	5	3
4	4	5	9	4	3	3	6
5	18	11	14	8	12	10	7

α	0.797
$\overline{X}$	3.636
p-value	0.0162

Table 4. Answers from the players of the gameplay questionnaire and results of statistic calculations o Cronbach's alpha and p-value of hypothesis T-Student test (without question *ii*).

the respondents is greater than three (i.e., since the scale of the answer goes from one to five, where five is the best value, totally immersed and one is the worst value, not immersed).

- H0: $\mu = 3$
- H1: $\mu > 3$

The results can be seen in Table 4, where it is possible to verify that the p-value was 0.0162, a very significant value because is smaller than 0.05 that allows us to discard H0 and accept H1. So, we can believe that flow state may be being reached for the majority of players, however, in this study were happened some unforeseen.

One problem that we were had was the fact that put young children to answer a gameplay questionnaire. They do not have the ability to maintain attention for a long time, and this was notorious in the last two questions (ix, x) that were open questions, about bugs of the game, because we had answers like qsdftak. For this reason, we do not have assurances about the data.

Pedagogical Evaluation

After the modifications to the game were completed, was created a study that intends to evaluate the didactic part of the game.

This evaluation must be carried with a control condition. Therefore, we need two classes of students from the same school year, and if possible from the same school or the same social context. This time, the objective is no longer to find

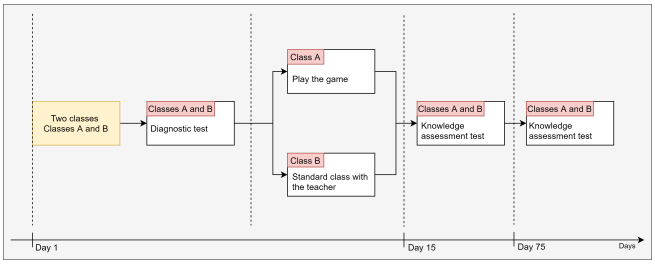

Figure 9. Outline that summarizes the planning of the study on learning that lasts 75 days.

problems in the game but to evaluate the performance of the game as an auxiliary teaching tool. Thus, it is necessary to verify its performance when compared to a class given by a teacher. In order to assess the knowledge transmitted to the children, in the short and long term, we divided this study into four stages of execution (see the schema of Figure 9:

- Phase 1: Carry out a diagnostic test on the topic;
- Phase 2:
  - Play Treme-Treme;
  - Attend a class on Earthquakes and tsunamis;
- Phase 3: Conduct an assessment test;
- Phase 4: Repeat the assessment test.

Phase 1 serves to ascertain the knowledge that the study participants already have and understand whether or not they can iterate in the study.

After evaluating the results of the diagnostic tests, Phase 2 can start. In this phase, one class will play Treme-Treme and the other class will be the control group, will not play the game, but will attend a class that addresses the same content on the topic.

After the game and the lesson are over, Phase 2 is completed, however, Phase 3 should only take place two weeks later and during that time between Phase 2 and the end of the study, the game must be removed from the site so that students in the class that had the lesson (i.e., the control group) do not have access to it.

Fifteen days after, both classes must accomplish Phase 3, which consists of carrying out a knowledge assessment test equal to the diagnostic test of the first phase. Two months later, in the fourth and final phase, the assessment test must be repeated again by the two classes to ascertain the retention of knowledge.

This study was designed to start when schools reopened in September-October, however, when we got a positive answer from the school, it was too late to finish the study in time. Even so, we began the evaluation on the 23rd of November 2020 and should be ended on the 3rd of February 2021.

Web Game Log Data

In addition to the studies planned, it is possible to analyze the data collected by the informal use of the game, through

Figure 10. Captured and summarized data about the main events of the House Mission level as well as the number of players at the beginning and in the end of the level.

the data collection system previously described that provides enough data about the game to extract meaningful information. (see Figure 10 for an example than can be seen on the web page).

From the data of the capture mechanism of December 22nd summarized in Table 5 where were analyzed 910 logs of players who started the game for the first time, only 833 started the first level, and just 271 completed the last level of the game. The level that presented the highest rate of loss of players was that of House Mission, where just over 31% of users did not complete the level. The levels that presented the greatest retention were of the Emergency Kit and tsunami, with the retention, respectively of 90.16% and 84.80% of the players.

With regard to learning, from the data collected it is possible to observe (see Table 6) that out of 396 users who took the questionnaires, 101 obtained a star, 156 two stars and 139 achieved three stars, which results in an average little bigger than two. We have no way of knowing if this knowledge was acquired with the game or if it was already with the players.

Evaluation on Different Devices and Browses

Since the game will be on a website accessible worldwide, it is important to evaluate it regarding its performance in different devices and browsers. This assessment was carried out in three different situations:

- As part of the *Explain to Me as If I Were 5 Years Old* project, created by Instituto Superior Técnico[9], and the project *A Terra Treme* from National Civil Protection[10], the site had more than 1.700 accesses, which allowed us to evaluate the performance of the game on different devices and browsers.

[9] `https://explicame.tecnico.ulisboa.pt`
[10] `http://www.aterratreme.pt/`

Levels	Initial Players Logs	Final Players Logs	% of Losses	% of Retention
Start the game	910	-	3.41	96.59
Introduction	879	-	4.21	95.79
Kit Mission	833	765	9.84	90.16
House Mission	751	487	37.82	62.18
Tsunami Mission	467	413	15.20	84.80
Night Mission	396	271	31.57	68.43

Table 5. Game retention rate by levels

	1 Star	2 Stars	3 Stars	Total	Average
Quizzes	101	156	139	396	2.10

Table 6. Performance of players in quizzes

- The online evaluation also made it possible to evaluate the game on different devices and browsers since each player played at home, on his machine, and in his favorite browser. At that time the data capture system was not yet operational, however, in the questionnaire, only three answers reported errors that could be associated with the devices and/or browsers they were using, a problem that was solved.

- The application that is in the play store has more than 100 downloads of the game that run on various devices and versions of android. To date, the app does not have any feedback commentary, which does not allow us to understand the repercussions of the game, however, the number of installations in the week of the National Civil Protection *A Terra Treme* project was 140 users, while the number of uninstallations was of 11 (7%).

Through Google Analytics it is possible to see what devices and browsers were most used by the users (see Figure 11) and observe that the game was used in many devices, browsers, and screen resolutions without registering any failures (which does not mean that they do not exist, they may simply not have been reported).

CONCLUSION

Earthquakes and Tsunamis can occur on Earth at any time and cause irreversible damage and loss. Given the imminent danger, it is important to invest in raising awareness in people. Based on the principle that prevention is currently the only way to minimize damage, this dissertation reported the steps that were necessary to take to complete the serious game, raising awareness about earthquakes and tsunamis started in 2014 with the aim of helping teachers to address the theme. This dissertation also described the mechanism that was developed

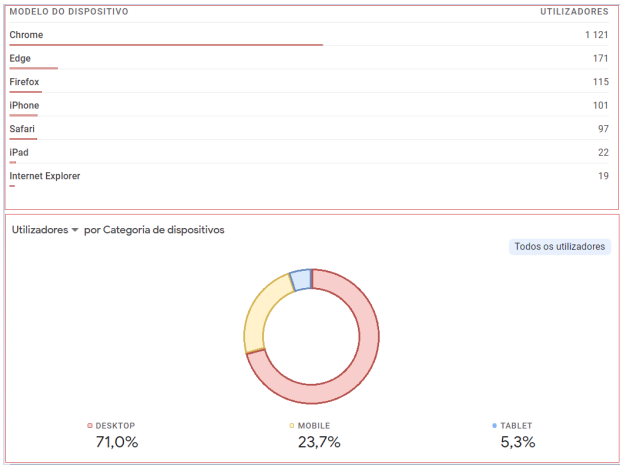

Figure 11. The different devices that are used to play Treme-Treme.

in order to be able to monitor the use of the game from a distance.

The results obtained from the evaluation show that the flow state may be reaching but without certainty due to the lack of control of the procedure that occurred during the testing. Although the data collected remotely seems to indicate that this state is not being reached by most, due to the loss of players, though these events are quite frequent in the game industry.

With regard to the evaluation of the content apprehended by the players, we did not obtain concrete results, given the impossibility of carrying out an evaluation due to the pandemic caused by Sars-CoV-2. Although the collected data shows a good score in the quiz of the game.

FUTURE WORK

As with any project, there is always something else more that can be done to improve the performance and experience of the player, so the following is a list of tasks that can be performed in the future in order to improve project performance

- *Evaluate the pedagogical part of the game*: It is important that the evaluation is carried out so that conclusions can be drawn about whether the game meets the proposed objectives.
- *Assess the gameplay of the game*: The results obtained in the tests performed online cannot be used to draw conclusions given the unfeasibility of the data, so it is important to run a new test.
- *Expand features of data page*: From the data captured it is possible to perform a wide range of statistics that can be incorporated into the page.
- *Increase the number of questions*: Now, each level of questions have only six distinct questions, it would be interesting to increase the number of questions.
- *Add more languages*: The number of languages should be expanded, adding languages from countries with high seismic activity.
- *Adapter the game for children with special educational needs*: During the development of the game were not considered children with special needs, however, that is a problem that should be solved in future versions of the game.

REFERENCES

1. Barreto, P. Treme-treme - a serious game to teach children earthquake preparedness.
2. Botelho, D. Treme-treme 2.0 - a serious game to teach children earthquake preparedness.
3. Breuer, J., and Bente, G. Why so serious? on the relation of serious games and learning. *Journal for Computer Game Culture 4 (1)* (2010), 7–24.
4. Cain, J., and Piascik, P. Are serious games a good strategy for pharmacy education? *American Journal of Pharmaceutical Education 79* (2015).
5. Charsky, D. From edutainment to serious games: A change in the use of game characteristics. *Games and Culture 5*, 2 (2010), 177–198.
6. Csikszentmihalyi, M. *Flow. The Psychology of Optimal Experience*. Harper Perennial, 1990.
7. Dewey, J. *How We Think*. Heath, New York, 1933.
8. Gee, J. P. Good video games and good learning. 93–105.
9. Goldberg, B., and Cannon-Bowers, J. Feedback source modality effects on training outcomes in a serious game: Pedagogical agents make a difference. *Computers in Human Behavior 52* (2015), 1 – 11.
10. Lucas, C. G., Bridgers, S., Griffiths, T. L., and Gopnik, A. When children are better (or at least more open-minded) learners than adults: Developmental differences in learning the forms of causal relationships. *Cognition 131*, 2 (2014), 284 – 299.
11. Montessori, M. *Education for a New World.* Madras, India: Kalakshetra Publications, 1946.
12. Ritterfeld, U., Shen, C., Wang, H., Nocera, L., and Wong, W. L. Multimodality and interactivity: Connecting properties of serious games with educational outcomes. *CyberPsychology & Behavior 12*, 6 (2009), 691–697.
13. Shaffer, D. W., Squire, K., Halverson, R., and Gee, J. P. Video games and the future of learning.
14. Shernoff, D. J. *The experience of student engagement in high school classrooms: Influences and effects on long-term outcomes*. LAP Lambert Academic Publishing, 2010.
15. Silva, M. C. Princípios de design e desenvolvimento para jogos digitais educativos para crianças com transtorno de déficit de atenção e hiperatividade.
16. Stapleton, A. Serious games: Serious opportunities. *Australian Game Developers' Conference 79* (2004).
17. Sternberg, R., and Zhang, L. *Perspectives on Thinking, Learning, and Cognitive Styles*. Educational Psychology Series. Taylor & Francis, 2014.
18. Strati, A. D., Shernoff, D. J., and Kackar, H. Z. Flow. In *Encyclopedia of adolescence*, R. L. (Ed.), Ed. Springer, 2012.
19. Sugarman, L. Experiential learning: Experience as the source of learning and development, david a. kolb, prentice-hall international, hemel hempstead, herts., 1984. no. of pages: xiii + 256. *Journal of Organizational Behavior 8*, 4 (1987), 359–360.
20. Willis, J. The neuroscience of joyful education. *Educational Leadership 64* (2010).