Treme-Treme 2.0 - A serious game to teach children earthquake preparedness

Duarte Botelho
duartebotelho@tecnico.ulisboa.pt

Instituto Superior Técnico, Lisboa, Portugal
June 2019

Abstract

Earthquakes continue to be one of the most destructive natural disasters. Even with the technological advances that have been made, it is impossible to predict when the next earthquake will occur or what magnitude it will have, so it is critical that everyone is prepared if of an earthquake. In 2014 a serious game was developed to teach people, particularly primary school children, which behaviours should be adopted before, during and after an earthquake. This game, Treme-Treme, had a huge success and 5 years later still continues to be used by elementary school teachers as a complement to teaching. In addition, it was also adopted by schools of children with educational difficulties, having a greater impact than initially thought. The opportunity has now arisen to continue the development of this game, and this work portrays the whole process inherent to the realisation of the new version. Over the years, Treme-Treme's code has become obsolete, so the game has been successfully rebuilt from scratch and improved, using a new platform, Godot. Game design was rethought and successfully implemented to provide an improved player experience. The results got with the tests show that Treme-Treme's new solution provides better engagement with children than the previous one, transmitting the intended pedagogical knowledge more effectively and representing a better tool for teachers.

Keywords: Serious game, Earthquake, Tsunamis, Preparedness, Children, Godot Engine

1. Introduction

Natural disasters are something common on Earth, differing only in the type of disaster depending on the area in which we are and the predictability of them. Scientists are able, for example, to identify the formation of a tornado as well as its trajectory and intensity with hours or even days in advance, there being specific times when the probability of a being generated is greater. In the case of earthquakes, prediction is a very hard problem that scientists investigate for more than 100 years. Therefore, it is important for us all to be aware of the danger to which we are subjected by living in an area with seismic activity.

It was in this philosophy that in 2014 the serious game Treme-Treme was developed. It was born from a project on seismic preparedness of the Department of Civil Engineering of Higher Technical Institute (DCE) under the European project UPStrat-MAFA (Urban disaster Prevention Strategies using MAroseroseic Fields and FAut Sources). The department wanted to create a serious game that would teach children about 8-10 years of age the dangers of earthquakes, as well as teach the best practices to take before, during and after an earthquake. The use of serious games has proven beneficial for the transmission of complex knowledge over short periods of time when compared to traditional teaching methods. These types of games have been applied in several areas, both children and adults, with very positive results. [5, 6, 7, 8, 10]

The previous version was developed using Unity, a free game engine that to make games in 2D and 3D, used by major manufacturers of video games such as CD Projekt. It was exported to 3 platforms, web, PC and macOS, all available for free and was the first integrated into a website specially dedicated to this game. Anyone could simply access http://www.treme-treme.pt/ and play directly on the browser, without having to download. However, at that time games exported to the web using Unity necessitated a special plugin, the Unity Webplayer, which became deprecated and no longer supported by browsers a few years ago. Therefore, the game is no longer available to play. In addition to this plugin, the source code itself is no longer available for reuse because Unity has evolved a lot in the last 5 years and the vast majority of the libraries used are now also deprecated.
With the need to keep the game available to the public as another tool to raise awareness about the dangers of earthquakes and how we should prepare, this thesis proposes a new solution, rebuilt from the beginning and with several changes, to re-launch Treme-Treme for free and on more platforms than before, and is also available in a mobile version, as it is a market that continues to expand and already has more players than any other platform.

2. Related Work
2.1. Serious Game
The term serious game is a buzzword and there is no consensus on its definition. Many tried to contribute with

<table>
<thead>
<tr>
<th>Definition</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>[9]</td>
<td>has selected two main definitions from [3] and [4], highlighting six key characteristics of a serious game.</td>
</tr>
<tr>
<td>A serious game is a learning process and teaching is a priority</td>
<td></td>
</tr>
<tr>
<td>It should still entertain the player because it continues to be a game</td>
<td></td>
</tr>
<tr>
<td>It is an application that use video game technologies</td>
<td></td>
</tr>
<tr>
<td>Multiple objectives should be address</td>
<td></td>
</tr>
<tr>
<td>Almost all fields are covered, from business and defense to education</td>
<td></td>
</tr>
<tr>
<td>Everyone can play it, no matter the age</td>
<td></td>
</tr>
</tbody>
</table>

Given this, we can define the term serious game as a video game, that can be played by every individual, independent of its age, and that has the main purpose of teaching one or multiple subjects, from a wide range of fields, while the player is entertained. However, it should not be played just for amusement, it is a pedagogical tool and should be treated as such.

2.2. Earthquake Preparedness
2.2.1 Before an earthquake
Preparation is the key to success. So it is at this stage that each of us must invest more time to prepare ourselves mentally as best we can for the disaster that may occur. There should be a concern to build an emergency kit with at least the following items:

- Water bottles (at least 1 litre/day/person, minimum, for at least 3 days)
- Canned food, easy to prepare for at least 3 days/person
- Medication for at least 7 days, especially if the person suffers from a chronic disease
- At least one battery-powered or hand-crank radio
- Batteries
- Multi-purpose tool with a sharp knife with a can opener
- Sanitation and essential personal hygiene items
- Flashlight
- Matches in a waterproof container
- Whistle
- Map
- One change of clothes
- Signal flare
- Contacts of the emergency services (police, fire, nearest hospital) and family
- Personal identification and important documents, or at least a water proof copy thereof
- Credit card and cash
- Games and activities for children

This kit should be constantly updated and be on a location easily accessible by all family members. In addition, there must also be a ready-to-use extinguisher, the ways of switching off gas and electricity must be known, furniture should be secured to the floor and walls, especially the heavier ones and the building should be maintained and repaired when cracks arise. This applies to both home and workplace. A meeting place should also be set so that all family members can come together. The area should be well known to all in order to be able to guide themselves and make the best survival decisions, such as going up to high ground in the case of coastal areas. Finally, it is always essential to carry out simulations whenever possible to test the reaction capacity of each in an environment closer to what would be experienced in reality and to test if the preparation measures taken are the best, adjusting what is not correct.

2.2.2 During an earthquake
Drop, cover and hold on. This is more important during an earthquake and one should always remain calm. If the person is inside a building, it must look for shelter under a strong surface, that can withstand eventual objects that can fall. A table or a bed is often the best place to find shelter, and you should always protect yourself from glass shards from mirrors or windows. Only in extreme cases, if none of the above exists, the person can shelter under a doorway, but this remains an extremely dangerous place to be. If gas is smelled, one should get out of the house and move as far away as possible.

In case of being on the street, it should take refuge in open places, without buildings, roads or poles nearby, since there is a greater risk of something heavy falling. If you are driving, the car must be stopped safely in an open and wide area. There is always the possibility of opening craters on the ground, so the person should take this into account.
2.2.3 After an earthquake

After the earthquake is over, you should leave home as soon as possible and always be safe, as the building has been weakened and there is a possibility of collapse. On the way, and only if it is safe, you should go get the emergency kit. Replicas will emerge, these will be less intense than the main earthquake but can be equally destructive, so it must be kept in a safe place when they occur. You should go to the place previously identified as a meeting point to meet with family members. If you live in a coastal area, you should go to the highest place possible, since there is a possibility of tsunami formation. The directions of the authorities should be followed. There is a possibility of a region being isolated for a few days, so you should always have the emergency kit with you. If you are sailing on the high seas, you should pay close attention to tsunamis, especially if the boat is small.

3. Treme-Treme v1

The Treme-Treme [1] is a serious game built around the theme of earthquakes and that takes the player to go through all the phases of an earthquake. It was developed for a master’s thesis in 2014 by Pedro Barreto from Instituto Superior Técnico, in partnership with the Civil Department of the same faculty and under a European project. This simple 2D game, single player, intended to convey complex themes to children between the ages of 7 and 10, especially in the classroom context, where a teacher could put their students to play to complement the theme taught during a lesson.

The game has three levels conceptualized, and only the first two were developed in a production version. As it fits in a European context, the game supported three languages, Portuguese, English and Italian, which could be changed in the settings from the main menu. On almost every screen a pause menu is available, which allows you to turn the sound on or off or exit the game.

The most relevant problems from the first version of the game that have been identified and solved by our solution are as follows.

Game doesn’t run on the website This is the most serious problem, which originated from the need to carry out this master’s thesis. The game must be made available for free and as easily as possible to the player. Therefore, one of the first things the player must have available when he or she accesses the Treme-Treme site should be the game itself, with no need to install anything, especially third-party plugins. It turns out that the game was made in a version of Unity that still needed the Webplayer plugin to run in browsers. Today this plugin has been discontinued and current browsers no longer support it. One of the solutions would go back to generating an export to the web using HTML5, for example, but since Unity has already evolved a lot in the last 5 years, it is almost impossible to import the existing code for a recent version of Unity, since most used libraries are deprecated. In explaining scenes, if the player clicks too many times on the button for a short period of time, sometimes results in the unexpected crash of the game. It is therefore very important that this problem is solved.

Level 1 is too big The first level, which corresponds to the construction of the emergency kit, is too large since it also encompasses all the explanation of what an earthquake is and the character’s choice. Therefore, this level could be divided into at least two parts to compartmentalize the topics.

Game progress not recorded If the player, for any reason, closes the game and goes back to running, all progress will be lost, having to start all over again. From a pedagogical point of view, this is not really a problem, because the player going through the whole explanation could assimilate concepts that in the first gameplay had not been so clear. From the point of view of the game itself, this is a problem as it adversely affects the player-game interaction.

Sound disabled by default Sound is something that completely turns a game. To do so, it must be on by default unless the player wants to turn it off.

English is the default language In the context of the European project, it is important that the game has English as default language. But since this is a Portuguese game, our language should become the main language when the game is first started or, if it is added, detect the language of the device and set it accordingly.

Game crash if next button is spammed In explaining scenes, if the player clicks too many times on the button for a short period of time, sometimes results in the unexpected crash of the game.

Italian is not fully translated Some strings were detected to be in English when they actually belonged to the set of Italian strings, such as “audio on” or “audio off”

Third level still not implemented The third level, although already conceptually done and already having all the necessary assets, is still not playable.

Poor version control The code of the first part of the project was placed in Bitbucket, the
quake is, the destruction that may cause to the rest of the game. It explains what an earthness to young children. The first level is the base of the three-level game that taught earthquake preparedness, this was the second splash screen and the sign for the main menu. In the old version, the splash screen is displayed that disappears after 3 seconds. In the new version, this was the second splash screen and the overlay window, consisting of a sprite and a label, was also removed. Something that was done in each commit.

4. Treme-Treme v2
4.1. Choosing a new development tool
As stated in the last chapter, Treme-Treme’s first version has been developed using version 3.x of Unity3D, which represented a major challenge to expand the previous work. Given this, there was the option to change the game engine to a better suited one for Treme-Treme. An alternative open source game development engine was considered, Godot. Its documentation provides a quick writeup that goes as follows:

Godot Engine is a cross-platform game engine to create 2D and 3D games from a single interface. Games can easily be exported to multiple platforms, including the major desktop platforms (Linux, macOS, Windows) as well as mobile (Android, iOS) and web-based (HTML5) platforms. It is free and open source and it will continue to be like that, driven and developed by the community.

In short, the engine transition from Unity to Godot was due to the following major reasons:
- Lightweight, Godot’s executable file has less than 40MB
- Available on Steam, with ”Overwhelmingly Positive” reviews, keeping me always updated with the latest version (currently 3.1.1)
- Ability to easily export the game to a large number of platforms with just a few clicks
- It is all there, build the scene and program the script in the same editor, with autocomplete and syntax highlight, no need to install third party heavyweight programs like Visual Studio
- Easily customizable on the project settings
- Ability to see the source code and talk to the developers to report an issue (or even solve it myself)
- Enough online resources, both in the documentation, which is extremely complete, as in the community, that teach to use the tool and to solve any problems that may arise
- The experience of experimenting with and learning a new programming tool and language, with which I had never worked, thus representing an extra challenge on a personal level

4.2. Redesigned Game Interaction Architecture
Treme-Treme was initially designed as a simple three-level game that taught earthquake preparedness to young children. The first level is the base of the rest of the game. It explains what an earthquake is, the destruction that may cause to the population either through the destruction of buildings or through tsunamis. This is also where the player chooses the character, Sunami or Terramota, and where the first mission takes place, building an emergency kit. Level two had the second mission, leaving a house slowly destroyed by a major earthquake struck and some aftershocks. Finally, the third level consisted of trying to reach high ground before a tsunami caused by the previous earthquakes reached land. Game progressed was not recorded, which meant that if the player exited the game, would have to redo all levels again. Audio was also the only game setting easily modifiable during gameplay, accessible through the pause menu. To switch language the player would have to press the back button through all scenes to reach the main menu. Once level two was reached, going back was impossible. In addition, the default language was English and sound was disabled. As the main menu do not have any text or indication that audio should be playing, players would have to start the first level and then realise that they did not understand the language. As for the sound, players could play the entire game without realising that sound was available but turned off.

To address all these problems, Treme-Treme’s design had to be rethought and the following changes should be made.
- Going to the main menu should be an easy and straightforward process and should be possible during gameplay
- Game progress should be recorded
- Sound should be enable by default
- Language should be set according to the device running the game

The player can now go to the main menu at any time during the game, using the designated button on the pause overlay menu. The title of this overlay window, consisting of a sprite and a label, has also been centred instead of having the sprite in the middle and the label on the right side. The background image is also darker, giving the more significance to this menu.

Some effects have been added to improve the game feel, highlighting the animation of shaking the main screen, which gives the beginning to the theme of the game, earthquakes. The splash screen of Unity was also removed, something that is automatically placed by this game engine in the free version. When the game is started, a splash screen is displayed that disappears after 3 seconds to make room for the main menu. In the old version, this was the second splash screen and the player had to click to disappear and go to the main menu.
4.2.1 Game Level Selection

This is where the player sees their progress in the game and choose the next level to be played. Figure 1 shows this new scene, which gave the player some information about each of the levels before they are played. To do this, all levels have an image and an animation that represents them.

Level 0: image of destroyed buildings that increase and decrease in size.

Level 1: image of the kit with all the possible items to be carried, spinning around it.

Level 2: image of the house from where the player will have to flee, shaking periodically since an earthquake is followed by aftershocks.

Level 3: image of the tsunami from, permanently locked and without animation.

Quiz: question mark rotating horizontally since these are levels with unknown questions.

![Image of level selection](image)

Figure 1: Treme-Treme's game level selection

The game level selection is not shown when the player unlocks a new level. The two current ways to show this scene are:

- The player is on the main menu and clicks the play button
- The player spends the 3 life-level lives at the house mission
- The player completed a quiz level

This scene comes to solve the difficulty of switching between levels without having to go through all the scenes that separate them. The game play is not broken by the transition between levels and reality is represented in a better way. The child should always be prepared for the eventuality of a catastrophe to occur, building an emergency kit that is put to the test soon after. It’s worth adding that when the player starts playing the levels, you will only return to this scene if you click the “Main Menu” button of the pause menu, if you complete the game in full on the non-Quiz levels (which at this point corresponds to completing level 2) or whenever a Quiz ends. When a non-level Quiz is finished, the next level is unlocked and the game proceeds there (at the end of the kit’s mission, level 1, the player immediately starts playing level 2, for example).

4.2.2 Level 0 - Introduction

This level corresponds to the initial part of the old level 1. Since it introduces essential concepts about earthquakes and, in turn, of the game, it will be approached as level 0. Like the old version, it consists of 4 scenes, each of the first 3 contains 2 boxes with a sprite to the left followed by text. In the last screen the player can choose one of the two possible characters, Sunami and Terramota, boy and girl respectively. The most noticeable change between the old version and the current was the removal of the scene that explained the controls because it is no longer suitable for the current times.

It consisted of a single text box with the text explanation that the player would have to click the mouse at the desired position for the character to move, accompanied by the image of a mouse. Given that mobile devices nowadays represent most of the devices used to play these types of games, with touch being used as input instead of the mouse and that the way of playing is transversal to many other current games, it was found that this scene could be removed from this level. If the player still wants to know which controls to be used, the same scene can always be accessed from the settings, clicking the Controls button. Level 0 does not reward the player with stars, as it is only an introduction to the game and represents no challenge to it.

4.2.3 Level 1 - Emergency Kit Mission

This level has as main objective the construction of an emergency kit. After a scene with an explanation of what needs to be done, the player enters the main level scene, KitMission. This scene, as Figure 2 shows, contains ten Sprite nodes, one for the emergency kit the remaining nine for each item that the player can choose to take. Each item spawn on a new random location everytime this scene is initiated.

![Image of emergency kit](image)

Figure 2: Level 1 - Kit mission

By completing this level, the player can receive between 0 and 3 stars, inclusive. Whenever the scene begins, it is assumed that the player has 3 stars and for each time the “OK” button is pressed while the kit is incomplete but with at least 1 item
already placed or poorly constructed, the number of stars is decremented. The player can try this level as many times as he wants, and after 3 attempts will always receive 0 stars. In addition, if the player places the wrong items in the kit and click on the OK button, the generic message will be shown saying that something is not correct. On the second try, if any of the items are still correct, an animation will be shown to give a hint to the player of what items should be removed.

4.2.4 Level 2 - House Mission

This is the most complex level of the game, both in terms of implementation and gameplay. At this level the player must escape from home and meet the parents while an earthquake is taking place, followed by several aftershocks. To reach the goal, you need to find hiding places to protect yourself from rocks, glass and furniture, turn off gas and electricity, and pick up a survival kit. This level consists of 6 main parts: canvas layer, camera, background, house, character and navigation path, organized as shown on Figure 3.

4.2.5 Quiz

These levels were introduced as yet another act of gamification to test the player’s knowledge about what they have just learned at each level. Thus, if the player does not receive all the stars of a Quiz as a reward, they will either go back to the Quiz or re-play the level to make the concepts clearer. This promotes the player’s engagement with the game. As this game was intended to be played in a classroom, these small levels are optional, so that the teacher may not include them in his class, asking questions or evaluating himself to his students. After the third question answered, a text message is shown to report their performance along with the number of stars won. Figure 4 shows an example of a correct Quiz answer.

4.2.6 Game persistence

Something missing in the previous version and that becomes more significant as the number of levels increases is the ability to save game progress. Nowadays, any game keeps some information, either locally or online through the creation of an account. Therefore, this functionality was implemented by saving the following global variables:

- **Sound**: boolean where true represents sound on and false sound off
- **Language**: string with the language locale to be used
- **Character**: string with the character name
- **Current scene**: string with the scene identifier where the game should be continued
- **Statistics**: dictionary where the keys are strings with the identifiers of the existing levels and the values an integer with the number of stars got, in the closed range of 0 to 3

Data is stored on the file `treme_treme_data.json`, located on the `user://` directory, which is a read-only folder, used for user resource files and unique on for mobile and consoles. This file is encrypted on mobile with the device’s ID to prevent file sharing however tampering is possible. On all other platforms, the file is encrypted with a hardcoded SHA256 key, preventing tampering (unless brute-force is used) but not file sharing. Data is written to disk when:

- The game is closed
- Some changes in sound or language settings are made
- A level change occurs
- A new character is chosen

4.2.7 Multi language support

Treme-Treme is a game planned to be played by children from different nationalities, therefore the first version had support for three languages, Portuguese, English and Italian and translations were stored on XML files. Godot uses CSV by default to integrate language on the game. Having said this, the XML files were migrated to a single CSV with the keys on the lines and the different languages on the columns. In addition, French is now fully supported.

5. Evaluation

Evaluation took place at Casa Pia de Lisboa, on April 23th 2019 with 44 students, split in groups of 4 with a total of 11 groups.
5.1. Methodology

Three methods were used in order to compare how both Treme-Treme versions transmitted the seismological knowledge to the children:

5.1.1 Observation

The children's behaviour and engagement were observed throughout the activity and some of the comments made were noted. This method is the best way to compare both of the game's clues since the former does not contain data persistence. By looking at, for example, which items to take in the emergency kit or how players die on the second level, we have a perception of how the knowledge is being passed and how they are learning. The constructive discussions that the children were having during the course of the game proved to be another way of obtaining relevant data to justify their choices. Teachers have also been observed to have a perception of the reaction to the game since the game should be made available by them in the classroom and is intended to know if it is a good tool.

5.1.2 Interview

It was not possible to gather formal consent to conduct individual surveys in time, so questions were made to each group before and after each session. Besides children, professors have been requested to answer some questions and provide some feedback from the changes made and how suited the game was to be used as a teaching resource. These questions have been made while the students played and after all groups completed the activity.

5.1.3 Data collection

The latest Treme-Treme version has the ability to keep log files of the activities, as detailed on 4.2.6, allowing us to have more groups trying the game at the same time and complementing the research with the time spent on each scene, of the retries on both Kit and House missions and the reason why the player died. Unfortunately, we could not extract any data from the previous version of the game since the code was not reusable or modifiable and my colleague only used the previous two methodologies on his evaluation.

5.2. Results

The results presented are divided into two components. In the first, a comparison is made between the two versions based on observation data, questionnaires and game logs. The second component portrays the special tasks that were asked of the children to evaluate the architectural changes made to the game. In these is first reported what flow expected to perform, followed by an explanation of what children actually did, based on behaviour observation.

During this evaluation, 4 groups of children were asked to test both versions in different orders to try to establish a method of comparison between the two. The biggest concern in doing this was that the children were biased because they had already gone through all the scenes, not paying as much attention as they would have if they were seeing them for the first time and completeness. But this was not revealed. The children gave as much importance to the first version they tried as to the second version, reading the whole theoretical part aloud in turn and debating which items should be placed in the kit or where they should be hidden inside the house. Because the results obtained did not prove to be biased, they were included in the graphs that followed on both versions. Our evaluation also include the data obtained in 2014 to assess whether the game still remains a current-day tool.

5.2.1 Goals

The work previous done established 5 main goals for Treme-Treme, which are still fundamental for us and are used to evaluate the accomplished work.

**Goal 1 - The player must know how to build a simple emergency kit and which objects are the most important for his survival**

This was the easiest and fastest mission level, where it was intended that only the strictly necessary objects be placed in the kit. All groups managed to pass this level, taking, on average, 72 seconds to do so. 64% of the groups collected 3 stars, 27% 2 stars and only one star in 1 of the groups, which corresponds to 9%. None of the groups received 0 stars, that is, everyone clicked the OK button with the kit partially or incorrectly filled in a maximum of 2 times. Compared with the results obtained in the version 1 evaluation, there was a huge discrepancy in the data, since previously 80% of the children failed 2 or more times. At that time the children did not know what objects to put in the emergency kit, but all had managed to complete this level, which indicated that while playing there was an apprenticeship of what was essential to transport to survive an earthquake.

It was expected that some of the objects were not identified by children, such as the radio that nowadays fell into disuse, with the emergence of smartphones, but this was one of the first objects to be placed inside the kit, revealing that the game continues to be acquired, even having spent half a
decade on its idealization.

**Goal 2** - The player should know where the dangerous and safe places are and what to do in each situation

![Figure 5: Sum of deaths, by type, from all groups](image)

This group of players, like the one who carried out the tests to the first version, showed to have a piece of good knowledge about where they should hide during an earthquake. As such, it became easier for them to identify the best places to protect themselves when the countdown reached 0. However, there were a large number of failed home-level attempts and recorded deaths are shown in Figure 5. The rocks were the source of the highest number of deaths since it covers most of the area of the house. Whether permanently, in all places where there is only one roof of the house, or sporadic, like the rocks that spawn randomly in the 6 possible sites, even if they are already covered by stairs, for example. In addition, the players decided to explore the various divisions of the house, even knowing that an earthquake was imminent, further increasing the number of deaths. This is not directly reflected in the player’s lack of knowledge about the occurrence of an earthquake, but rather that it is a game and that the exploratory factor is always present, especially in children. Another problem that also contributed to some deaths was that the path was not perfect and when players clicked under the bed, the character began to descend the stairs as it was the closest point to the given place as input.

As for the identification of safe places where the player should be housed in case of an earthquake, most groups were able to quickly identify these sites. Only two groups were killed at first by the facts (exploratory and bug of not being able to hide under the bed) previously stated.

With the exception of 1 group, everyone has gone through at least one replicate in at least 1 of their attempts. Something relevant was the fact that all the groups left the house before the first replica happened, in the attempt in which they managed to pass the level. This may demonstrate that the children have been discovering the ideal actions by trial and error, perfecting their knowledge the attempt until they feel perfectly at ease to face an earthquake.

**Goal 3** - The player must be aware that gas valves and electrical switches must be turned off before leaving home

In the earlier assessment of the development of the first version of the game, players were forced to turn off both electricity and gas. The results showed that 92.50% players did it and they were able to understand the importance of doing it in the real world. In the second version, as it was reflected in the first one after the evaluation, to complete the level, the player is only obliged to turn off the gas to complete the level, being the electricity optional. It was observed that most players failed to immediately understand what was supposed to be done, even with the balloon containing the image of the gas tap/electricity switch near the character was shown, with 55% and 45% of the groups dying at least one for gas and electricity, respectively. One group only completed the second level on the third attempt, finding shelter correctly but dying 2 times in the process, one for electricity and one for gas. On that attempt we observed that the group turn off both the optional electricity and the mandatory gas, proving that they learned with the mistake.

**Goals 4 and 5** - The player must understand how dangerous earthquakes can be, how much time a person takes to protect himself and the importance of leaving home after an earthquake to his family emergency meeting point far away from buildings

The players showed they knew they had to leave the house as soon as possible, but out of curiosity, they were more interested in exploring the various divisions of the house. On average, players took 48 seconds to complete the second level and the fact that they did it once did not represent a significant reduction in time from a later attempt. As a rule, attempts, where players completed the level, were the longest, even knowing the map. It was observed that players in the first phase were disoriented when what to do to complete the level, as well as what was the countdown. After they knew what the second was, as soon as he appeared, the first instinct was to find shelter, even while already in the kitchen with the gas off and near the exit door. After leaving home, all groups understood that they were supposed to find the meeting point and none returned home, having the arrow with the text that indicated the way to play an important role in this decision.

5.2.2 Gameplay

There was a noticeable improvement in the difficulty of the game, and the vast majority of partici-
pants now think the game is well balanced, as seen on Figure 6. This reveals that even with the introduction of questions, which by and large make the game more difficult and boring, it remains something that children are interested in playing.

Figure 6: Game difficulty - comparison between both versions, with data from the previous evaluation

Regarding game controls, there is a slight improvement from the previous experiment to the current, as seen on Figure 7. However, some participants still think on some occasions the controls should be better. This fact was noticeable by observing their behaviour at the house mission when trying to hide under the bed. As the stairs are very close to the bed, the navigation mesh is not ideal and when the player clicks under the bed, the closest detected point is halfway down the stairs, inducing confusion to the player. Nevertheless, this better result may relate to the fact that the participants now use smartphones to play this type of games instead of a PC with a mouse, which have similar controls to Treme-Treme. This means that both the initial choice of controls, back in 2014, and the decision to maintain them were the best option. Unfortunately, it was not possible to test the gameplay on a mobile device to prove this hypothesis.

Figure 7: Controls difficulty - comparison between both versions, with data from the previous evaluation

5.2.3 Special tasks

These special tasks have been asked of the children as a way of verifying that the changes made to the game with the development of the new version contributed positively to the same. As it was previously impossible to return to the main menu after starting the game and being already at the kit level, making it impossible to go to settings, for example. Thus, it was initially the children who turned off the sound of the game, something that was already possible on the previous version. In doing so, the children had to open the pause menu, which had the option of returning to the main menu. Then they were asked to change the language of the game, testing the way to the main menu. It was finally asked to change the character, something that was also impossible to do on the first version if the player was already on the menu of the house. The latter required the player to think about all the game architecture since there is no direct path to character change from the level selection scene.

Disabled sound: In this case, the objective was to turn off the sound while playing a level, the expected flow would be:
1. Click on the pause button on the top right corner
2. Click on the sound button

This flow was easily achieved by the group from the fourth grade, however similarly to the previous task, the group from third grade was not able to associate that the pause button would allow them to change some game settings.

Change language: The objective was to change the language from Portuguese to English while playing a level, the expected flow would be as follows:
1. Click on the pause button on the top right corner
2. Click on "Main menu"
3. Click on the settings button on the bottom left corner
4. Click on the language button until "English" appears

The children demonstrated confusion and none of the groups was not able to achieve the objective. After getting feedback, the root was the lack of association that the pause button would take them to the main menu which would allow them to switch the language.

Choose a different character: On this final request, the objective was to choose a different character than the one previously selected before playing the house mission and two main flows could have been taken. The first would be:
1. Click on the pause button on the top right corner
2. Click on "Main menu"
3. Click on Play
4. Choose the first level
5. Click on the next button on the bottom right corner until the player choice scene appears

The second possible flow was:
1. Click on the pause button on the top right corner
2. Click on "Main menu"
3. Click on Play
4. Choose the first level
5. Click on back button on the bottom left corner
Both groups were able to complete the task, choosing flow number one, as they did not remember that the second level has a previous button. While executing the task we could observe that the current implementation is not ideal and changes should be done so that player can easily switch the chosen character. This was also reinforced by observing the behaviour of other groups which did not perform this task and were composed by children from both genders, playing the game in turns.

5.3. Final Remarks
In this chapter, we evaluated and compared both Treme-Treme versions. The main objective was achieved as the children demonstrated to gain more knowledge about earthquakes preparedness after playing the game. The objective of the newest additions was also achieved. Gamification proved to be the key element to provide higher engagement between the children and the game. To get all possible stars, they replayed the levels where their performance was lower over and over again. Quiz levels were also good to foster knowledge, generating healthy debates to choose the correct answer. The interviewed professors also gave good feedback and considered Treme-Treme’s second version a good addition to the classroom when they addressed the subject of the earthquake.

6. Conclusions
This project proved to require a greater effort than originally envisaged. Although the game has already been made available for several years, the whole code has become obsolete by using old libraries and programming languages that are no longer supported by Unity, making it impossible to work on what already existed. It was necessary to redo the game in full, without the possibility of reusing code that already existed. All the animations had to be also redone from scratch and the location of the objects was approximated of the original version. It was thus impossible to perform the third level on the available time.

Gamification was introduced as the game was rebuilt, which made it even more appealing and aroused much more curiosity in children. It was quite gratifying to see that the children loved the game and were able to learn from the work that was developed.

It is noteworthy that after the evaluation the game was already in exhibition on Dia do Técnico, on May 23, 2019, in order to promote the game laboratory of the Instituto Superior Técnico, where it received excellent feedback from those who played it. The game was available to be played along with other games developed by the masters of games, being one of these the first version of Treme-Treme. The activity lasted 3 hours and was visited by children and parents.

References