TÉCNICO LISBOA

Treme-Treme 2.1

Improving a Game for Children Awareness of Seismic Phenomena

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Abstract

Children are usually the age group that is most affected by natural catastrophes. Therefore it is extremely important to educate them on what they need to do in case of danger to protect themselves. To achieve this goal appeared Treme-Treme, a serious game that endeavors to educate school-age children on how to behave before, during, and after the occurrence of an earthquake and/or a tsunami. The game was first developed in 2014 in a partnership between the Departments of Computer Science and Engineering and Civil Engineering for a European project on Urban Disaster Prevention Strategies using Macroseismic Fields and Fault Sources. As the game continued to be used, it became evident, in early 2018, that 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 concluded, and since this game is still active in multiple schools, it was important to complete all the changes to provide all the elements for the students.

Thus, this work comes as a follow-up to the previous one, with the missing levels being migrated to the new platforms and making several changes to the structure and functioning of the pre-existing game. In addition to completing the restructuring of the game, this work also resulted in a remote monitoring mechanism of the performance that provides researchers/project managers with information on both the game and the player, both nationally and internationally.

Keywords

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

Resumo

As crianças são uma das faixas etárias mais afetadas por catástrofes naturais. Portanto, é extremamente importante ensinar-lhes o que fazer, em caso de perigo, para se protegerem. Com esse objetivo em mente surgiu o Treme-Treme, um jogo sério que visa educar crianças em idade escolar sobre como se comportar antes, durante e após a ocorrência de um terramoto e/ou tsunami. O jogo foi desenvolvido pela primeira vez em 2014 em parceria entre os Departamentos de Engenharia Civil e Engenharia Informática, para o projeto europeu Urban Disaster Prevention Strategies using Macroseismic Fields and Fault Sources.

À medida que o jogo continuava a ser usado, tornou-se evidente, no início de 2018, que algumas mudanças eram necessárias, não apenas para acompanhar as novas tecnologias web e móveis, mas também para melhorar alguns dos recursos já existentes. No entanto, esta reestruturação não foi concluída, e como este jogo ainda se encontra em utilização em várias escolas, foi importante completar todas as alterações para fornecer todos os elementos aos alunos.

Assim, este trabalho vem como seguimento do anterior, onde foram migrados todos os níveis que faltavam para a nova plataforma e realizadas varias alterações na estrutura e no funcionamento do jogo pré-existente. Para além de concluir a reestruturação, deste trabalho resultou também um mecanismos de monitorização à distância do desempenho, que oferece aos investigadores/responsáveis pelo projeto, informações quer do jogo, quer do jogador e ainda do alcance a nível nacional e internacional.

Palavras Chave

Terramotos; Tsunamis; Jogos Didáticos; Crianças; Catastrofes Naturais; Treme-Treme; Aprendizagem Baseada em Jogos

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Introduction

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Disasters happen on our planet quite frequently, creating a trail of destruction and/or death wherever it goes. Humanity has been trying for many years to minimize the damage caused by these events (e.g., landslides, hurricanes, floods, or fires) by establishing centers and foundations around the world, for forecasting and monitoring natural disasters. With the scientific advances made so far, scientists can now predict and monitor some types of catastrophes, such as tornadoes. In this case, scientists can predict/identify the formation of the tornado, as well as the trajectory and strength. However, earthquakes are not part of this set of catastrophes which can be predicted in a reasonable time. The same is also valid for tsunamis, although they are a little easier to predict than earthquakes, as tsunamis are usually a consequence of other phenomena (i.e., a tsunami usually follows a major earthquake, and it is possible to predict the tsunami during the earthquake), but, although scientists have more time to act than a tsunami, it is still not enough.

In these situations of extreme natural events, children are more vulnerable than adults, because they react psychologically in different ways. Their coping strategies are not as developed as those of adults therefore during and after disasters, they may not be in a position to understand and come to terms with what has happened. This is why children are more overburdened and lose control more quickly [4]. Therefore it is essential to alert and educate them about the dangers of these situations. Also, they are much more available and open to learning this type of content than adults [5], playing an important role in the transmission of knowledge (i.e., they alert the adults to this situation, stimulating dialogue, and, beyond that, the adults are the people who can help them in their preparation).

To address these concerns, the work reported in this document was used to develop an improved version of a game, which 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.

1.1 Motivation

Complex themes, such as disasters, are often difficult to teach to children due to their young age and because it is not easy to keep their attention. So to teach these topics to children, the idea of teaching them through a game came up. Multiple works in literature [6–9] indicate that a good 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 [10]. With this in mind, this work describes a game, called Treme-Treme[1], which aims to teach children to act during the occurrence of these catastrophes (i.e., tsunamis and earthquakes).

[1] https://www.treme-treme.pt

In Portugal, this game has been used by several schools as educational support material. In addition, the Civil Engineering Department carries out several awareness-raising actions in schools and events, 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 [11]. However, as time went by, the version of Unity[2] on which the game was developed was discontinued and the game was no longer updated. For this reason, began in 2019 a restructuring on a new platform needs to be completed.

1.2 Context

Portugal is a country with a moderate seismic risk, and because it is by the sea, the likelihood of a tsunami following an earthquake is very large. Following the idea that prevention is the only solution, in 2014 was born Treme-Treme, a serious earthquake and tsunami awareness game for primary school children [11, 12]. This project was started by a partnership between the Department of Computer Science and Engineering (DEI) and the Department of Civil Engineering (DEC) from Instituto Superior Técnico, under the European project Urban Disaster Prevention Strategies Using Macroseismic Fields and Fault Sources (UPStrat-MAFA). The project had the goal of teaching children aged between seven and nine years old how to act before, during, and after the occurrence of an earthquake or/and tsunami.

Several studies have revealed that seizure of complex knowledge improves with the use of serious games than when compared to traditional teaching methods [6–9]. In addition, brain-related scientists and psychologists explain how the brain learns best when a person is having fun [13], which proves that the game may be a great option, giving the child a moment of fun while learning.

> "Brain research tells us that when the fun stops, learning often stops too." - Judy Willis [13]

1.3 Objective

Treme-Treme was firstly developed between 2013 and 2014 using the technologies that were available at the time [12]. However, it was six years ago, and the version of Unity that has used is now discontinued, and as such, the existing web version stopped working. Due to the fact that children are increasingly using mobile devices such as smartphones and tablets, it is now also appropriate to make the game available on these platforms. For these reasons between 2018 and 2019 the game suffered several changes and was migrated to a new platform, Godot[3], capable of exporting to both web and mobile platforms.

[2] https://www.unity.com
[3] https://www.godotengine.org

At that time, Duarte Botelho, responsible for the platform modification, despite making some changes and adding new elements to the game, only managed to complete the first two levels (which did not allow the project to be completed). So the game stopped providing the tsunami and the post-earthquake levels. Therefore the objectives of this work are to migrate these levels to Godot and to correct some other problems that were identified either in the current or previous versions of the game. This update (i.e., the migration and the correction of the identified problems) is necessary for the game to achieve its intended purpose – *teaching while playing*. 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 to not lose track of the game, the creation of a tool that allows the reponsibles for the project to monitor the game was also an important objective.

In conclusion, the main objectives that this work proposes are (i) the migration of the rest of the levels from Unity to Godot, (ii) the correction of the errors in the existing levels that prevent the aforementioned objectives from being fulfilled, and (iii) the creation of tools to analyze the performance of the players during the game.

1.4 Contributions

This dissertation resulted in a serious game and a data monitoring system that brings contributions to the future of awareness against earthquakes and tsunamis. More concretely:

- **Participation in awareness events:** This new version of the game has already been used in several awareness campaigns on earthquakes and tsunamis (e.g., "Explica-me como se tivesse 5 anos" from Instituto Superior Técnico, "European Researchers Night" promoted by the European Commission since 2005 and "A Terra Treme", an event held by the National Civil Protection (ANEPC)). These events took place online and had hundreds of participants.

- **Use in schools:** Before this game was completed, it had already been used in several schools. Now that it is complete, it will provide players with a greater moment of fun and learn, where they will be offered a different class than normal (i.e., with space for debate between teachers and students).

- **General use:** The game is online and so anyone from anywhere in the world can play it, being possible to learn while having fun in the comfort of their home. The more people are alerted to the dangers of these natural disasters, the more likely they are to be saved when one occurs.

- **Data monitoring system:** The data system developed allows the responsible for the project to not lose track of the game and monitor their performance. Through it, they are also able to perform tests, statistics, and even find problems that may exist. In this way the monitoring of the game is straightforward and the problem-solving process is faster and more effective.

1.5 Organization of the Document

The present document is structured as follows. In Chapter 2 are presented some concepts necessary for understanding the rest of the work, and some educational theories that will be used throughout the development of the game. This chapter also describes some important facts and warnings about earthquakes and tsunamis that helped in creating the concept of the game. Chapter 3 explores work done in this area, related to serious games about earthquake or tsunami and evaluate them according to the metrics and theories that were outlined in the previous section. This section aims to explain what is being done in the literature, and how we can do something better that covers the failures of others. Chapter 4 gives a brief introduction to the game, describing the different levels and the different steps the player has to go through to gain knowledge as well as all the interventions the game has undergone, this chapter also describes the changes carried out in the version that already existed and the additions that were made, namely new levels. Chapter 5 describes the system created to monitor the performance of both the game and the player, as well as the reach of the website nationally and internationally. Chapter 6 discusses the mechanisms used to evaluate the work as well as a detailed analysis of the results obtained in order to verify whether the proposed objectives are achieved. Finally, Chapter 7 presents some future work, together with a brief conclusion of this document.

2

Background

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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.

2.1 Earthquake

Our planet is made up of plates that make up the crust of the earth, called tectonic plates. These constantly moving plates accumulate energy that can be released smoothly or suddenly. When energy is released abruptly, it gives rise to a high magnitude (i.e., a measure of the earthquake size) earthquake, causing a trail of destruction. These catastrophes, when they occur, usually create a large number of casualties and a large area of destruction, not being possible at this time to forecast them in useful time. Thus it is essential to master preventive measures such as:

- Prepare an emergency kit;
- Develop an emergency plan with the family;
- Pre-arrange a safe hangout (in an open space on the street);
- Identify the safest places, such as a table or bed to shelter;
- Identify the most dangerous locations in order to maintain a safe distance;
- Fix furniture and heavy objects that may fall;
- All family members should know how to turn off the electricity and cut off water and gas.

During an earthquake, people should go to large locations without buildings, lamps, or other objects that may fall. Once a safe place has been found, people should stay there, with the help of their emergency kit, until a civil protection message is given that it is safe to leave. If they are at home, they should protect themselves in a safe place, away from falling objects, wait for the earthquake to end, and only then leave the house (and taking care to turn off the gas and electricity to avoid fires). After the earthquake, people must continue to be aware, since an earthquake typically brings with it a set of replicas. These and other measures can be found with more detail, for instance, in the ready[1] website.

2.2 Tsunami

A tsunami is a wave caused by a displacement of a large volume of water. These movements can occur in places with a high water mass as in oceans, seas, rivers, or lakes. This phenomenon usually arises from earthquakes, but can also occur due to volcanic eruptions, underwater explosions (e.g., the detonation of nuclear bombs), landslides, or meteorite impacts.

[1] https://www.ready.gov/earthquakes

Tsunamis most often cause a large number of deaths and almost complete destruction of the sites it strikes. As a result, is essential to be alert if you are in a zone of risk (e.g., beaches or islands), as well as check if there are any of the following evidence (i.e., they can be a clue of a tsunami that is approaching):

- Earthquake: As previously described, an earthquake has a good chance of causing a tsunami;
- Tide retreat: During wave formation, it pulls a large volume of water causing sudden tide retreat;
- Sound of an airplane jet: The formation of the wave creates a noise similar to that of an airplane jet;
- White horizon line: A tsunami wave bursts before reaching the coast, forming a white foam line.

If one or more of these warning signs occur, people should move as far as possible from the coast (i.e., about three kilometers), and head to high places such as hills and mountains. If this is not possible, the best decision is to go up a house over 30 meters high. After the wave has passed it is important that people stay safe, since, like earthquakes, tsunamis also have replicas. These and other measures can be found again with more detail in the ready[2] website.

2.3 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. However, between these games, there is a variant that is serious games. These types of games are not primarily intended for entertainment as their purpose is to be used to promote learning and behavior change. These games can be used in several areas, such as education, health, marketing, and other businesses and industries [3]. They are designed to solve problems in the most varied areas and involve challenges and rewards, using the entertainment and engagement components provided when the player is playing.

Therefore, the slices that interest us in serious games are those that are geared towards educational types of games that have well-defined learning results [14]. Generally, game-based learning is designed to provide the player, during the game, the necessary knowledge on a given topic in order for the player to retain and apply that subject to the real world[4]. These games provide positive emotions, improve learning, and have the advantage of requiring greater player involvement (compared to other mechanisms for obtaining knowledge such as books), which provides a greater level of immersion, providing the player with a safe space where they can experiment without consequences[5].

[2] https://www.ready.gov/tsunamis
[3] https://grendelgames.com/what-are-serious-games/
[4] https://edtechreview.in/dictionary/298-what-is-game-based-learning
[5] https://grendelgames.com/what-are-serious-games/

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

Table 2.1: Balance that must exist between difficulty and skills in order to achieve *flow*, according to [1–3].

2.3.1 Games in Education

Children are naturally curious and unrivaled in energy, so it is crucial to capture their attention so that you can teach them anything [15]. For this, there are professionals who dedicate their lives to study techniques to maximize the profitability of learning moments.

The development of serious games is based on the theoretical foundation of constructive learning theories, where many articles in the literature show that knowledge is created through experience while exploring the world and performing activities [16–18], experimental learning is advocated by a number of renowned psychologists like Lewin, Dewey, and Piaget, who denounce the way people transform experiences into learning [18, 19].

Gee et. al [20] described in his work some of the characteristics in games that contribute to the learning of those who are playing, against 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. For him, these need to be inserted in an environment where people around them talk about the subject. This is not the case in a game because, as pointed by the author, a game can speak for itself since it generates actions, consequences, and their respective feedback.

Other authors believe that games provide the player with 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 [21].

Games also have the power to capture the attention of the students since without actions the game does not evolve and with wrong actions, the game ends in defeat. These situations lead the player to concentrate, think, and focus on taking the best actions to achieve the best results. During the game, the student is always the active agent, while in normal classes the student is a passive agent who absorbs information from an active agent who is the teacher [21].

2.3.2 Serious Game Development Theories

One of the main challenges of a serious game is to reconcile fun and education because, as we have seen, the brain maximizes the apprehension of content when it is fun [13]. To achieve balance between fun and learning there are a few factors to keep in mind in order to maximize the experience:

- **Game difficulty:** During the development of a serious game, we must constantly take into consideration the age group for which the game is intended since it is essential 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. This is where the *flow* concept created by Mihaly Csikszentmihalyi comes in that characterizes the psychological state of a person, more precisely, it refers to a state of mind characterized by focused concentration and elevated enjoyment during intrinsically interesting activities [22]. According to the book *Encyclopedia of Adolescence* [23], the player can fit into one of the four quadrants of the Table 2.1 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 narratives, 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 (i) a combination of design, (ii) story, (iii) rewards/achievements (i.e., it is important for the player to feel rewarded for what they are correctly doing, in order to avoid frustration), (iv) conflict, and (v) other elements of the game, that could make the experience more fun.

- **Feedback:** When we perform a task where we do not know what is expected from us (i.e., we do not have prior knowledge, or we do not know what is being evaluated), it is extremely important to receive feedback. In a serious game, this is not an exception, feedback can be the difference between the child learning what is supposed, and not learning at all.

  If the feedback is not continuous the player will overcome challenges without knowing if it is playing correctly, or not, which will result in the player not acquiring the competence that the challenge wanted to convey. However, continuity is not the only factor that we must take into consideration, it should not be solely in the form of audio, this must be a combination of audio and text given the young age of the target audience who has not yet mastered the art of reading, but it should not be too long to do not be boring, but at the same time it must be precise (i.e. it should not cause confusion or doubt in the head of the player, still giving the idea that one wants to convey).

In short, 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. [24], 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 where at each level the player acquires skills. Each level, therefore, has to have better or distinct skills. In this way, we can maintain the *flow* state in the player.

In a book published in 1990, Csikszentmihalyi [1] reveals that during the *flow*, 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 [25] 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). In order not to break this state it is necessary that all previous points are carefully achieved in order to always reach and keep the player in the *flow* state.

3

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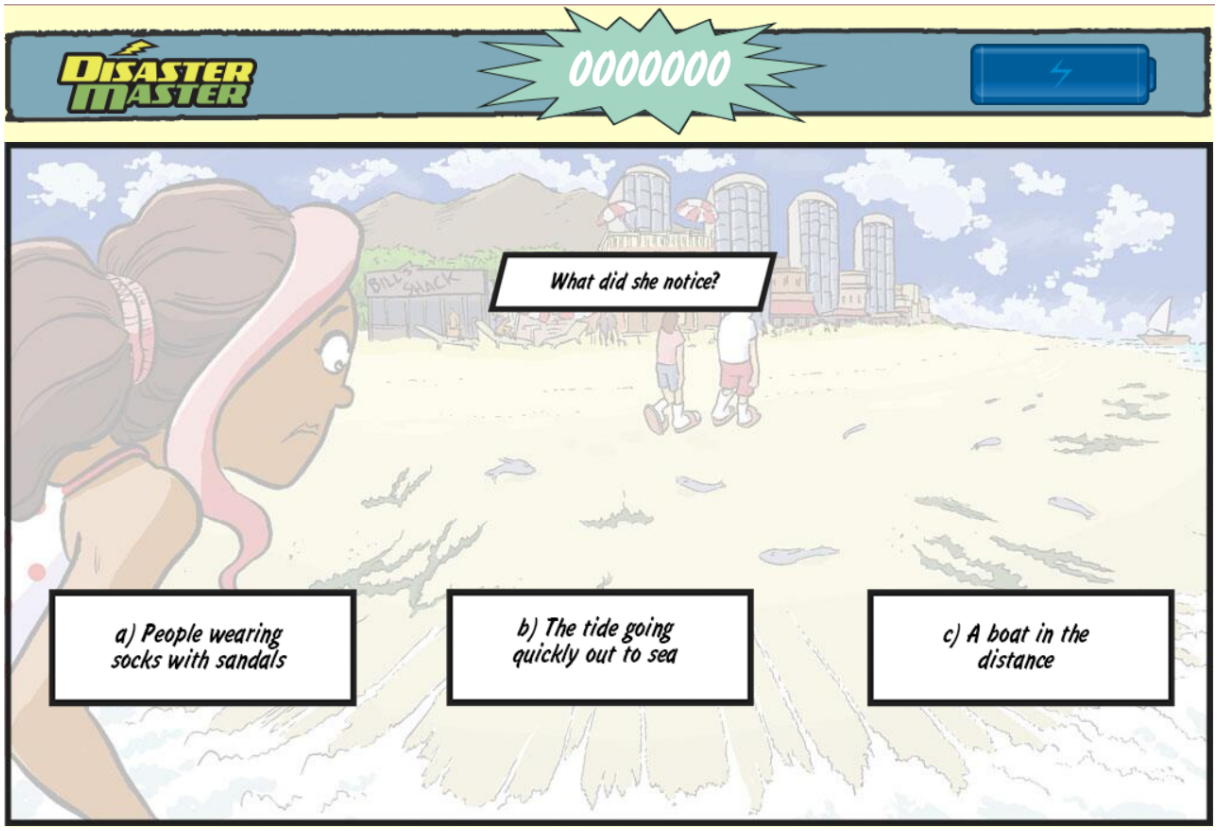

Figure 3.1: Disaster Master is a serious game from *ready.gov* that aims to teach children to survive various types of catastrophes. This figure depicts a question that appears in the Tsunami level.

The area of game-based learning has been growing in recent years [26], and although there is much work in the field of game-based learning that seeks to educate children on a wide range of topics (e.g., mathematics, geography, or idioms), 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 and compare them with the methodologies described in the previous section.

3.1 Disaster Master

Disaster Master[1] 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, as shown in Figure 3.1, are inserted throughout the story, defining the next step.

[1] https://www.ready.gov/kids/games/data/dm-english/

Feedback is inserted into the story as follows: (i) wrong answers are scolded by a character in the scene that explains the correct way to act, (ii) correct answers are praised. This way, all players can finish the game with the level of knowledge that the creators want to convey, even if the questions fail. This game is perfectly divided into eight levels, where each level represents a catastrophe, allowing the child to easily associate the knowledge learned with each event.

In terms of entertainment, the game integrates the various elements we saw in the previous section, such as design, story, rewards (given in the form of points whenever a player answers correctly), and conflict (created when the child has to choose an answer). And that is where the game disappoints, because, as we saw earlier, multiple-choice questions (as well as dense blocks of text) in large quantities drive the child to exhaustion and interrupt the immersion of the player and the *flow* state. This game combines both the two types, being composed solely of dialogue-based stories and multiple-choice questions. In this game, the attention of the child is expected to progressively decrease due to disruption of *flow*, immersion, and attention to the dialogue, which leads to another problem since the feedback is integrated into the dialogue that the child stopped reading.

3.2 Build a Kit

Build a Kit[2] 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 (e.g., board games, books, pet food, diapers, and baby food without any indication during the game which there is a baby). 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. Feedback in this game is given in text form after placing all the objects in the backpack. The feedback is objective, clear, short, and effective allowing the player to understand what he is doing right and wrong without bothering him.

In this game, all the levels have the same difficulty, there is no increasing evolution of the skills throughout the game and can, as we discussed, lead to a break in the *flow*. At the level of entertainment, this game has no story and there is no conducting wire between each of the levels. The design features a large number of clickable and non-clickable elements that can confuse the player, as shown in Figure 3.2.

[2] https://www.ready.gov/kids/games/data/bak-english/index.html

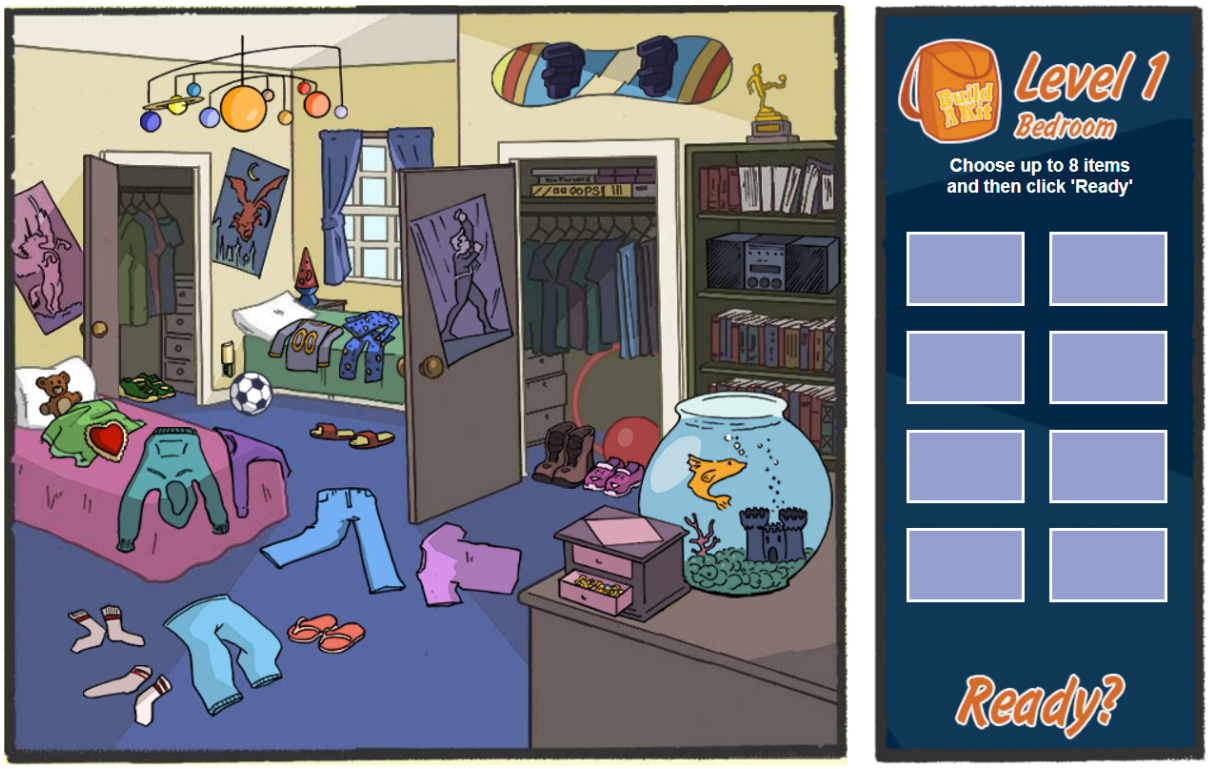

Figure 3.2: From the same collection as the game Disaster Master, Build a Kit, is an important game that teaches how to build an emergency kit for multiple situations.

3.3 Natural Disaster Survival

Natural Disaster Survival[3] is an online game in which the goal of each player is to survive natural events – see Figure 3.3 for a screenshot of the game.

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. The feedback from this game is not the best, as there is no information as to whether the local chosen for protection is good or bad (i.e., the player has to wait for the disaster to see if loses one life or not, but at this point, it may be too late to look for a new place, eventually dying without knowing where we should be hiding).

When the catastrophe ends, all survivors return to the waiting room and a new scenario is generated and a new catastrophe will occur. This dynamic of random catastrophes allows the difficulties and abilities of the game to be varied, keeping the *flow*, although it is interrupted as the player spends in the waiting room (however, since it is an online game, it is difficult to circumvent this waiting room mechanic).

[3] https://www.roblox.com/games/189707/Natural-Disaster-Survival

Figure 3.3: 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.

Being an online game, this game has in its favor the fact that the player is not alone and can be inspired by the moves of other players, as happens in real life, which can provide truth and realism to the scene. It also features a chat that may or may not ruin the idea of immersion. If the chat is used as a simulation of a smartphone, where we can ask for help and tips from friends on the contact list (as it can happen in real life), chatting is a great idea and brings immersion benefits as it creates realism, but if chat is used as in some entertainment-only online games, where chat conversations are completely parallel to what is going on in the game, chat can spoil immersion and knowledge acquisition because it causes distraction to the player.

3.4 Little Panda Earthquake Safety

Little Panda Earthquake Safety[4] 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.

[4] https://bit.ly/2Yj2SvK

Figure 3.4: Little Panda Earthquake Safety is a game where the character has to be prepared to overcome the many challenges that an earthquake entails.

At the end of each level, a set of four multiple-choice questions are presented to consolidate the contents covered in the level. This game features a very wide range of ages and very different stages of brain development. While a child from three to six years old is in the pre-operational phase, where symbol mastery occurs, a child from seven to eleven years old is in the concrete operational phase, in this phase she learns the mastery of classes, relationships and numbers and how to reason [27, 28]. In each of these phases, children need different stimuli, as psychologist Jean Piaget explains [28], so it is not advantageous to put them all in the same group.

Due to this need for distinct stimuli, this game, with regard to difficulty, will not be suitable for both groups. Being that, according to user comments, this game is quite simple for children over the age of five/six, which is in line with what Piaget says in his work. As mentioned before, this lack of difficulty will interfere with the immersion of the player (who will not feel challenged), not providing the fun and knowledge needed to achieve the goal of the game.

One more factor that large age ranges affect is the feedback. This game presents feedback in the form of audio integrated into the speech of the characters. However, this feedback is long and uses a very slow and calm speech, causing, sometimes, annoyance to players (according to some reviews of the game). We saw earlier that feedback must be given in a combination of audio and text form, and that it should be short and effective. However, as this game also integrates non-school age children, who cannot read, they chose not to provide textual feedback. Nonetheless, this factor again harms older players in the target audience.

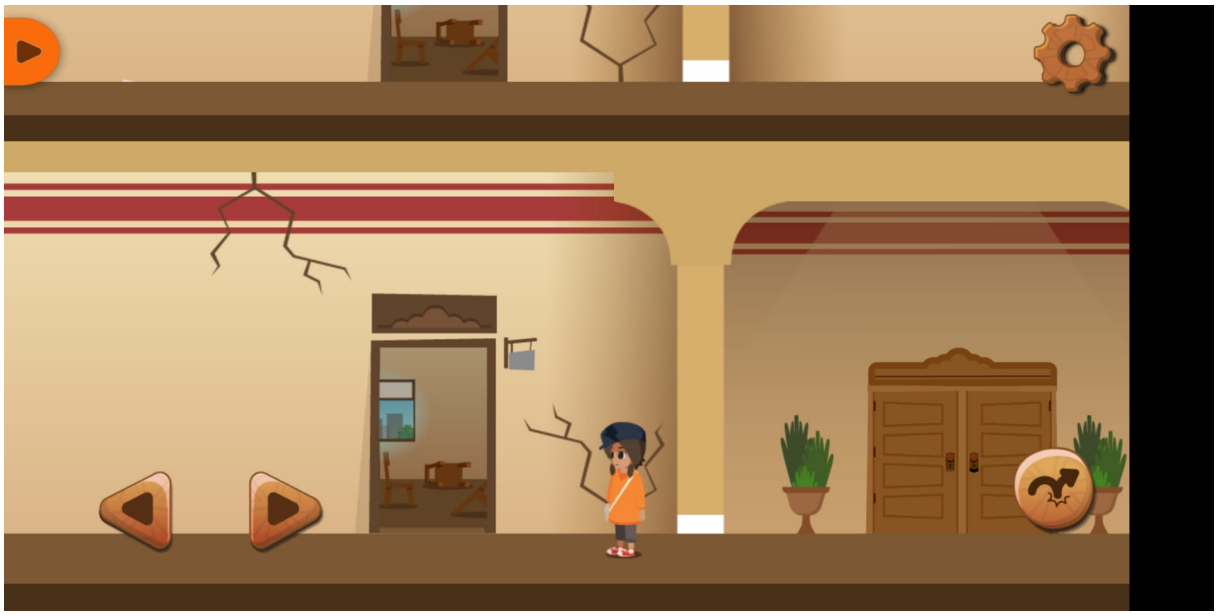

Figure 3.5: Tanah, an Opendeream mobile game, where the character has to complete several missions to escape from an earthquake.

3.5 Tanah: The Tsunami and Earthquake Fighter

Tanah[5] 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. During the game, the player is faced with multiple-choice questions when crossing with other characters, 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 issues 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.

The game is structured in levels and with increasing difficulty as proposed by Csikszentmihaly [23], however, the feedback is absent, either during mission accomplishment or answers to questions, where the player has no indication that he has answered correctly. This makes the player not sure if he is acting correctly, sometimes not knowing what to do to complete the level and getting "stuck" on a level. From that moment on, where he does not know what to do, he leaves the *flow* state.

3.6 Overview

Looking at all the games we saw in this chapter, it is noticeable from Table 3.1 that the topic of earthquakes is starting to get more covered, but that tsunamis are still a short-addressed subject in the games

[5] 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 3.1: Summary of the phases of the earthquake that each game presents.

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 aims to address these shortcomings currently existing in the mentioned games, presenting a game that conciliates all stages that both earthquakes and tsunamis have while maintaining the fun and maximizing the learning of the player.

4

The Game

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Figure 4.1: Treme-Treme game - Kit level.

Figure 4.2: Treme-Treme game - House level.

Treme-Treme is a serious game that seeks to teach children, ages between seven to nine years old, to act before, during, and after the occurrence of an earthquake and/or tsunamis. The goal of the game is to help the main characters (i.e., named Sunami and Terramota) to prepare and survive the catastrophes. To achieve this, they need to build a survival kit (Figure 4.1) with everything that is needed for their survival well in advance (before). After building the kit, they should be able to escape a house (Figure 4.2) during an earthquake and know how to handle their replicas (during). As the possibility of a tsunami occurring after an earthquake is quite high, our characters are taken to the beach where they have to escape it on the verge of a coming tsunami (during) and finally, to be safe, they must be able to reach a safe rendezvous where the rest of the people are and walking through the city streets after the earthquake has passed (after).

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. The game can be currently found on their website[1] and in the playstore[2]. On the website, it is possible to find the latest version of the game together with and a downloadable version for Windows and macOS, with some more information about the project where the game is inserted.

4.1 Game Description

Before beginning the description of the process of developing the game, is necessary to talk about the game and explain how the levels work, what happen during the levels, and witch are the details necessary to understand the description of the development of the game.

Treme-Treme begins in an initial menu, that takes us to a screen where it is possible to choose the character of the game. After that, appears the level selection menu that starts with an introductory level where concepts about earthquakes (and some game mechanics) are introduced.

[1] https://treme-treme.pt/
[2] https://play.google.com/store/apps/details?id=pt.treme_treme.game&hl=en_US&gl=US

After that, there are four levels (Kit Mission, House Mission, Tsunami Mission, and Night Mission - in the order presented). Each level has an extra level of questions, totaling five multiple-choice questionnaires, composed of three questions each. Each one starts with a short textual introduction that mentalizes the player to the challenges that he has to overcome. The levels also have a score (i.e., a maximum of three stars and a minimum of one star) that composes the rewards mechanism used to evaluate the performance of the player during the challenge. Stars assignment is also used in levels with quizzes.

In addition to these game menus, the game has two more interaction menus. Initially consisted of three different menus corresponding to the three main screens of the game (i.e., main menu, level selection menu, and game pause menu). Currently, these three menus have been reduced to only two where it is possible to (i) change the language of the game, (ii) view the controls, (iii) view credits, (iv) reset the game, (v) pause the game and (vi) leave the game. There is also a button in the upper left corner of all screens to mute the game.

4.1.1 Emergency Kit Mission Level

This level consists of the creation of an emergency kit that will be used in later levels. For the creation of a kit, the player should choose six of nine objects (water, batteries, flashlight, book, radio, canned food, whistle, console control, and stuffed toy) that are arranged above a table and put them on a backpack. The level ends when the player puts all of the six correct items on the backpack.

4.1.2 House Mission Level

This level begins in a normal house composed of rooms with normal objects specific to those rooms (e.g., furniture, windows, lamps, tables, bedroom, etc.). The player can explore those rooms but at any moment can start a countdown to the beginning of an earthquake. While the countdown does not arrive at zero, the player should find a place (that he thinks is safe) to protect himself. If the player chooses a bad spot, he loses, but if it chooses a good place, he can progress to the next challenge (i.e., turn off the lights). Moments after the first earthquake comes up a new earthquake (a replica), and the player should act the same way as the first earthquake. Before leaving the house the player should catch the emergency kit backpack and turn off the gas. The level ends when the player gets to leave the house.

4.1.3 Tsunami Mission Level

Tsunami Mission Level starts in a local where there is a tsunami alert. The player should walk until the meeting point but on the way, he needs to choose if he goes to the beach or to the mountain. If the player chooses the beach, he dies in the wave, if it chooses the mountain, he lives.

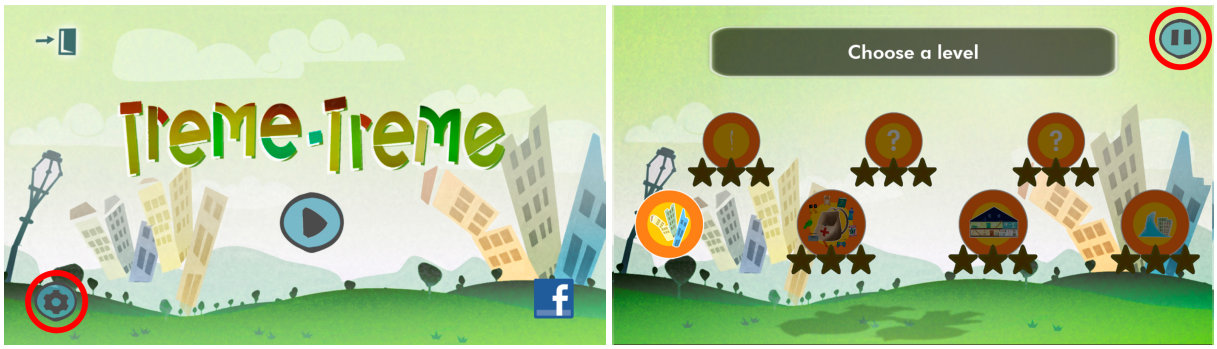

Figure 4.3: Main menu and game menu from the previous version.

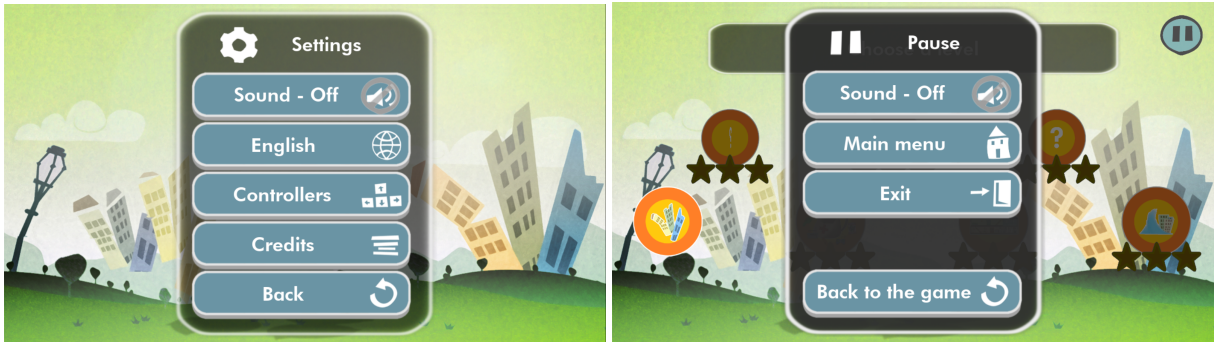

Figure 4.4: Settings menu and pause menu from previous version.

After that, at any moment, the player can choose an object of the backpack (i.e., the whistle that was chosen in the emergency kit level) to call help and conclude the level.

4.1.4 Night Mission Level

This is the last level and occurs after the earthquake and tsunami levels. At this level, the player has many obstacles that need to surpass, such as holes, falling buildings, and electric poles (i.e., similar obstacles that could face in a real earthquake). This level begins in the night, so the player needs a flashlight to be able to see the way. This item can be founded on the backpack, and similar to the previous level, the player can also choose any item of the backpack at any moment. In the middle of the level, the player also faces the end of batteries in the flashlight, thirst, and hunger. The player needs to arrive at the end of the level without fall in the holes and keep himself away from the buildings and electric poles.

4.2 Game Changes

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.

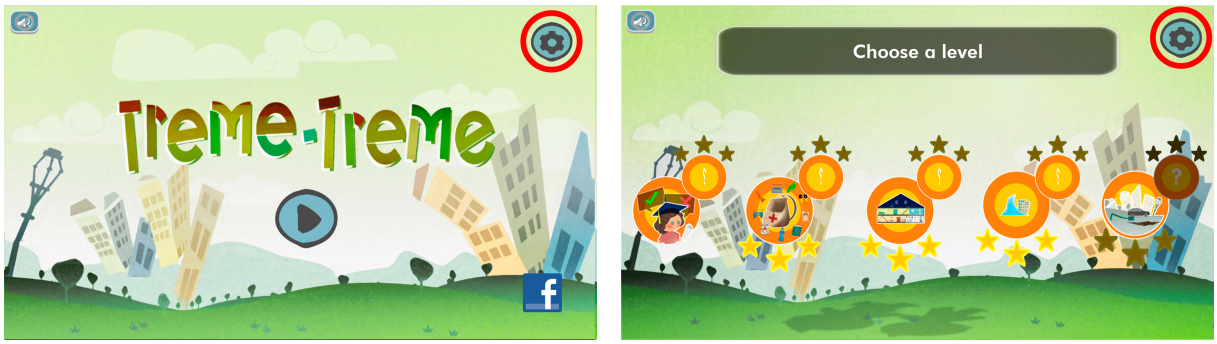

Figure 4.5: Main menu and game menu from the current version.

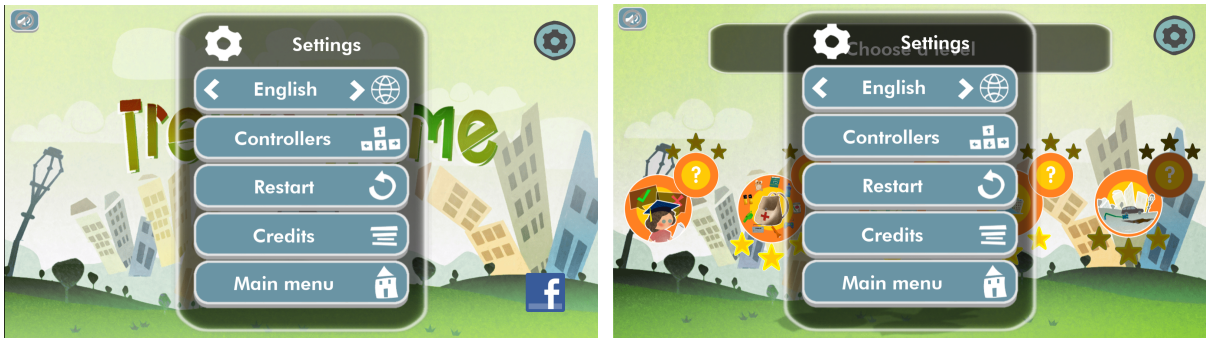

Figure 4.6: Settings menu and pause menu from the current version.

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.

After the challenges were identified, the process of developing the levels and correcting the errors that were necessary, to not only complete the list of tasks that Botelho [11] left but also to solve the problems found in the demonstration carried out at the school, started. After the implementation was completed, an evaluation was performed to test the performance of the game, and new errors were corrected with the collected data. The next sections describe the development process and the changes that the game has undergone.

4.3 Interaction Menus

The first major change that was made in the game was the reconstruction of the game menus, in particular the pause menu, settings, and level selection, since they did not comply with basic rules of interface design as can be read in the sections below.

4.3.1 Levels Menu

The levels menu 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 (see Figure 4.3 on the right).

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 history, they are extra levels that the player may or may not complete (see Figure 4.5 on the right). Removing them from the central line does not interfere with the progress of the story and keeping them close to the levels shows the dependence that the quiz has on the levels.

These issues were resolved by restructuring the menu where, in addition to correcting the problems, the icons for the new levels and questionnaires were added (see Figure 4.5 on the right).

4.3.2 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. Among these heuristics, a norm is described, which is consistency and adherence to norms (i). The principle describes that a system must look the same, act, and operate in the same way. Similar components must: (i.i) have a similar appearance, (i.ii) they have similar uses, (i.iii) the same action must always produce the same result, (i.iv) the function of the elements must not change, and (i.v) the position of the standard elements must not change. Another of the heuristics on Nielsen's list is: making the state of the system viable (ii) which describes that (ii.i) the interface must provide direct ways to perform tasks, and (ii.ii) the effect of actions on objects must be visible, users should receive feedback on what is happening in the system [29, 30].

Currently, none of these principles were respected in the creation of the pause or settings menus, since depending on the screen the same button is not presented in the same appearance (i.i). On some screens, the pause and settings buttons were not positioned in the same place on the window (i.v), the settings button on Screen 1 and 2 represented in Figure 4.3 did not have the same design (i.i) and did not have the same options in menu (i.iii).

Some important actions could only be carried out in a single menu on a specific screen (ii.i), such as changing the language. The only screen where it was possible to change the language was the first screen depicted in Figure 4.4, where there was no indication about the current language, which led the player to pass the window without realizing that the language was not correct. Once this window is advanced, the player would always have to return to it any time he wanted to change the language.

This action had to be carried out even if it meant abandoning the game (ii.i). If the player changes the language as the screen has no text, the effect of that change was not visible (ii.ii).

The solution was to redo the menus by correcting the flaws. The buttons were all placed in the same location on the screen (i.e., top left corner, following the rules used in other games on the market – see Figure 4.5), the settings menus on Screen 1 and 2 became the same and the option of changing the language became available in both menus. The option to mute the sound 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. In the previous version, if a player that already had finished the game, to start the game again, had to delete the page history. Finally, when the player wants to close the open menu, as represented in Figure 4.6, he can do it in two ways, by pressing the back button or by clicking anywhere on the screen outside the menu, which was not possible in the previous version.

4.4 Emergency Kit and House Mission

The version of Duarte Botelho [11] was developed in *GLES3* (that maps to OpenGL 3.3 on the desktop, OpenGL ES 3 on mobile and WebGL2 on the web[3]), however, before starting to play with the game code, a quick search was carried out on the compatibility between this option, since in his thesis Duarte stated that *GLES3* could not be supported by older hardware [11]. 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* to make way for Vulkan, and for that reason, in its documentation announces that the use of WebGL2 is not recommended due to its expected removal without replacement[4]. All of this led to the abandonment of *GLES3* to start using *GLES2* (that maps to OpenGL 2.1 on the desktop, OpenGL ES 2 on mobile, and WebGL 1 on the web) which, because it is older, is better supported by older machines and since it is believed that the game runs in a classroom context where schools are not equipped with modern machines, it is important to keep the game running on these devices.

With the change from *GLES3* to *GLES2*, some features the were already implemented at the level of the Emergency Kit and in the House Mission stopped working, and had to be redone using tools that *GLES2* supports. An example of this is all the particle systems hitherto implemented since they used the GPU to process the particles. It was necessary to redo all these systems using particles in the CPU. The electricity wire was also one of those affected elements by the exchange of versions of WebGL and needed to be redone.

[3] https://bit.ly/3loTqS8
[4] https://bit.ly/3kqEmCn

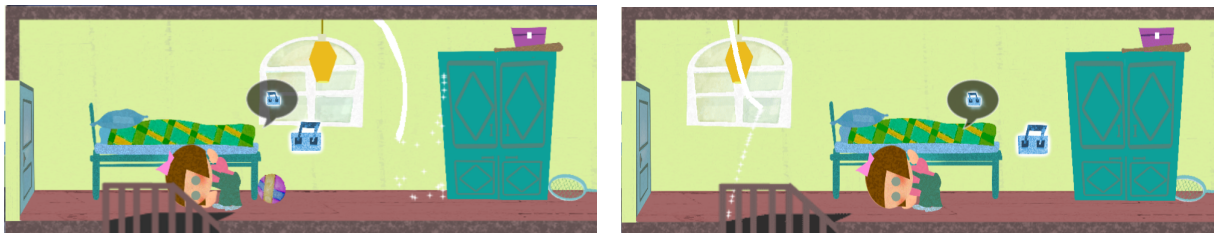

Figure 4.7: Home Mission level room scenery from previous version versus current version.

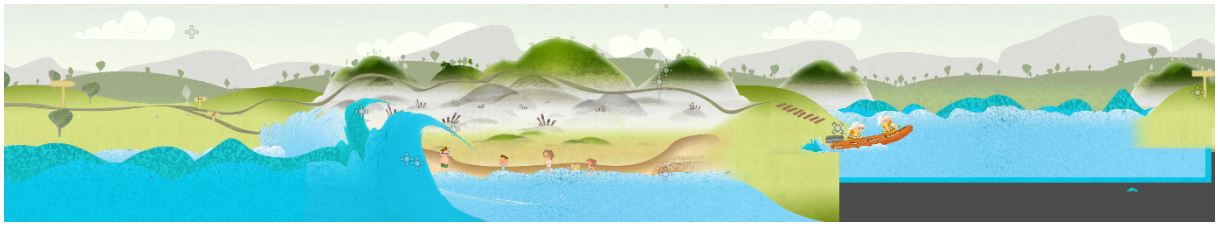

Figure 4.8: Scenery used in the Tsunami level.

To simulate the effect of the wire, a rope was developed composed of five rigid bodies joined by *PinJoint*[5] (i.e., the structure used to join rigid bodies) which, after applying the laws of physics, behaves as a string (see Figure 4.7).

In addition to these changes, it was also necessary to correct some details that hindered the gaming experience. The scenario underwent changes in the area of the bedroom since the colliders and the player jammed or performed wrong actions ending up causing the player to lose the game.

4.5 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.

4.5.1 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 last restructuring of the game last year.

The prototype is no longer in operation, so it is necessary to integrate it and adjust it to the new version of the game. For this, the first step that was taken to start the process was to recreate the scenery that can be seen in Figure 4.8. 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 from C# to GDScript.

[5] https://bit.ly/2UlTOVS

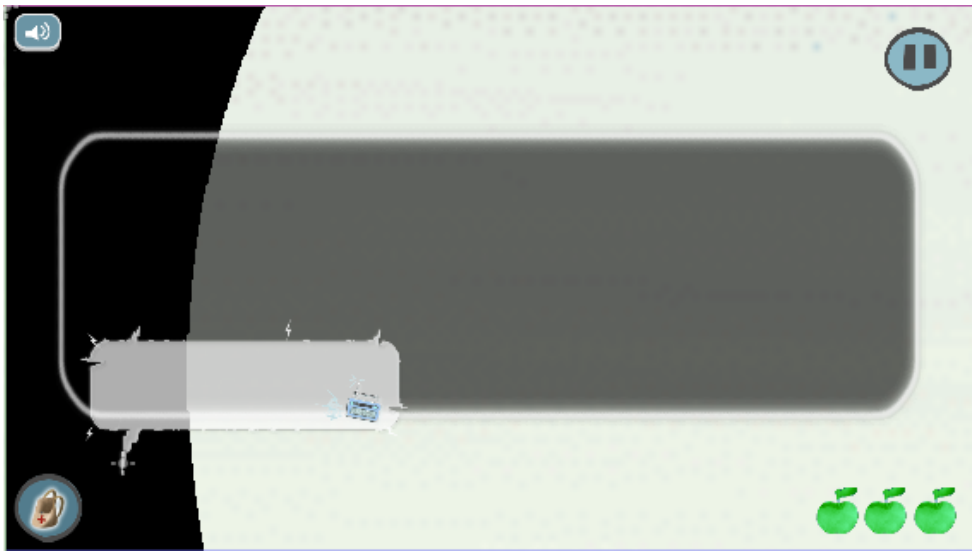

Figure 4.9: Tsunami and Night Mission level canvas layer.

Note that some elements used at this level, were common to the House Mission level (the pause menu, the fade-in and out shader, about 90% of the camera and much of the movement of the character), and for that reason, they will not be described in this document but can be consulted at [11].

4.5.1.A Canvas Layer

The canvas is a layer in the game that is independent of the game camera, having its own static camera. For this reason, it is a layer that does not move, whatever happens. It is in this layer that the elements that are fixed on the screen are located, such as the pause button, sound button, the life bar, the Emergency Kit button, and the fade-in and fade-out shader that are, respectively, the open and close of all the levels. All feedback and radio item messages that appear during the game will also be in this layer. When creating a scene, Godot automatically defines an empty default canvas layer, which must be replaced by a developer-defined canvas layer. The canvas layer defined for this level can be seen in Figure 4.9.

4.5.1.B Character

Most of the functionalities related to the player, such as the ability to walk, have been reused. However, since at the Home Missin 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.

Figure 4.10: Emergency kit with items to use at Tsunami and Night Mission levels.

4.5.1.C Emergency Kit

The emergency kit is a container of items that the player has to choose at the first level of the game. At any level the player can choose an item from the container and use it, meaning that the emergency kit must always be available, so a button was placed on the canvas layer that gives direct access to the kit. 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 triggering the corresponding action:

- Water and food: Whenever one of these items is selected, the health bar increases, and particles are emitted which are used to indicate the health was added.

- Flashlight and batteries: These items are useful just for the next level (i.e., the tsunami level does not require the player to use them), but as expected the flashlight is used as a light source.

- Radio: The radio item is intended to resemble a conventional radio that passes news (see Figure 4.11 for an illustration). This radio has a circular buffer with four message strings and alternates these messages on the screen. Each string remains visible in the canvas layer for two seconds and then disappears, one second after the message disappears, the next message from the buffer appears, and so on until the player stops using the radio.

Figure 4.11: Representation of the radio item in operation.

- Whistle: This item serves for calling for help at the end of the level, and for that reason he has a radius of action, outside of which he does not work. This radius of action was made through a collider that does not work as an object collider. Whenever the player collides with this collider, the whistle's functionalities are available, and when it stops colliding, the functionalities become unavailable again and the whistle becomes useless. When the player uses the whistle within its range of action, a boat appears that sails to the place where the player is. The boat will help the player to reach the other bank and therefore also has a collider. When the character collides with the collider, the boat starts moving and takes the character with it.

4.5.1.D 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. However, when the wave hit the characters they were projected into the air. This problem was solved by transforming the sprites into Kinematic Bodies that responds to the laws of physics. Two colliders have also been placed that act as a floor so that the characters do not fall, and a ceiling so that the characters are not projected by the impact, since the wave collider projects them upwards due to the inclination (see Figure 4.12. In case the player collides with the wave he loses and the level starts again.

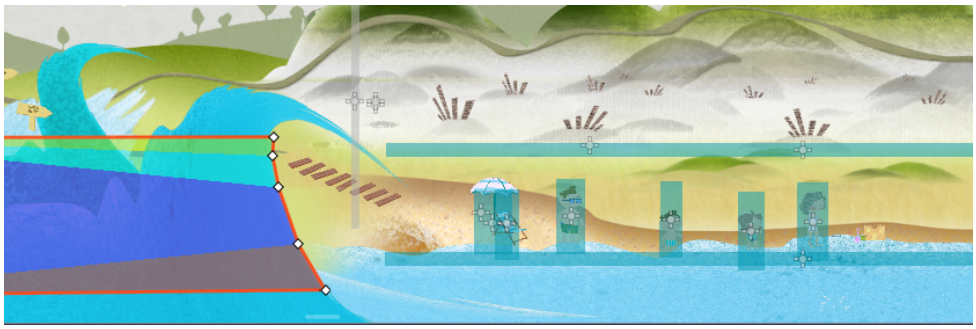

Figure 4.12: Colliders used to simulate the tsunami on the beach and encourage people to move.

Figure 4.13: Scenario used in the Night Mission level.

4.5.2 Night Mission

The level of the Night Mission occurs, as the name implies, during the night and after an earthquake/tsunami, where the player has to face the dangers associated with a post-earthquake. Similar to the previous level, the first stage of development was the creation of the scenario (see Figure 4.13).

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 (i.e., flashlight and batteries) are now useful. When the flashlight is turned on, the mask of the player is changed to one with a wider field of view. Initially, when the flashlight was used, a timer was triggered at the end of which it would turn off and only turn back on when the batteries were changed. At that time the items disappeared from the container after being used, simulating the reality that the items are depleted. However, in the evaluation that will be described later, it was noticed that the timer did not work since the kids took so long to pass the level that instead of changing the batteries once as was supposed, they ended up needing to perform this action more than once, an act that was impossible since the items were for single use. The solution was to stop using the time and it will pass use the progression of the level that when the player arrives in the middle of the level is emitted a signal that informs that the batteries of the lantern are over and the flashlights turnoff, in addition, the items started to be of multiple-use.

When the player finishes this level the game ends, and to celebrate the victory of the player, fireworks are launched. The fireworks were created through a particle system with three launch points, where every single one emits twenty particles per second.

4.6 Increase the Number of Questions per Level

With the increase in the number of levels, it was necessary to create two more questionnaires levels. 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 (i.e., Portuguese, English, Italian, French, and Spanish). 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.

This addition was due to the fact that in each questionnaire the player has to answer three questions and when a user misses a question the correct answer is presented. In case he wants to repeat the level to improve his score, as the buffer for each level only contained three questions, the questions presented the second time were exactly the same, for which the player already knows the answers. Since now there is a buffer with six questions, it is possible to vary the questions. A function has been added that randomly chooses for each level, three questions out of six to present in quizzes. Thus, if the player repeats the questionnaire, the chances of all questions being repeated are lower.

4.7 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 were too large (more than 100MB) for the web, 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 4.14 (I), taking a long time to load (more than two minutes).

The first idea to try to solve this problem was to find a way to reduce the size of the file where the game is. Assuming that the complete package could not be used, the initial resource package was divided into six smaller ones, so that each level was in a different package. Thus, at the beginning of the game, the package that would be loaded was *Resource Pack 1*, as represented in Figure 4.14 (II), which would be approximately one-sixth the size of the initial package, taking much less time to load. The remaining packages would be loaded during the game in the background, as they were requested, and the Scene Tree was being rebuilt. In this way, the time that the player would wait would correspond to the time needed to load around one-sixth of the initial package ($\approx$ 20MB).

This idea was implemented, but it only worked when the game was run locally once Godot is only prepared to load local files. Therefore, the only way to rebuild the Scene Tree would be to force the player to download the game. For this reason, this solution, despite solving the problem of the game taking a long time to load, could not be applied to this case and was discarded.

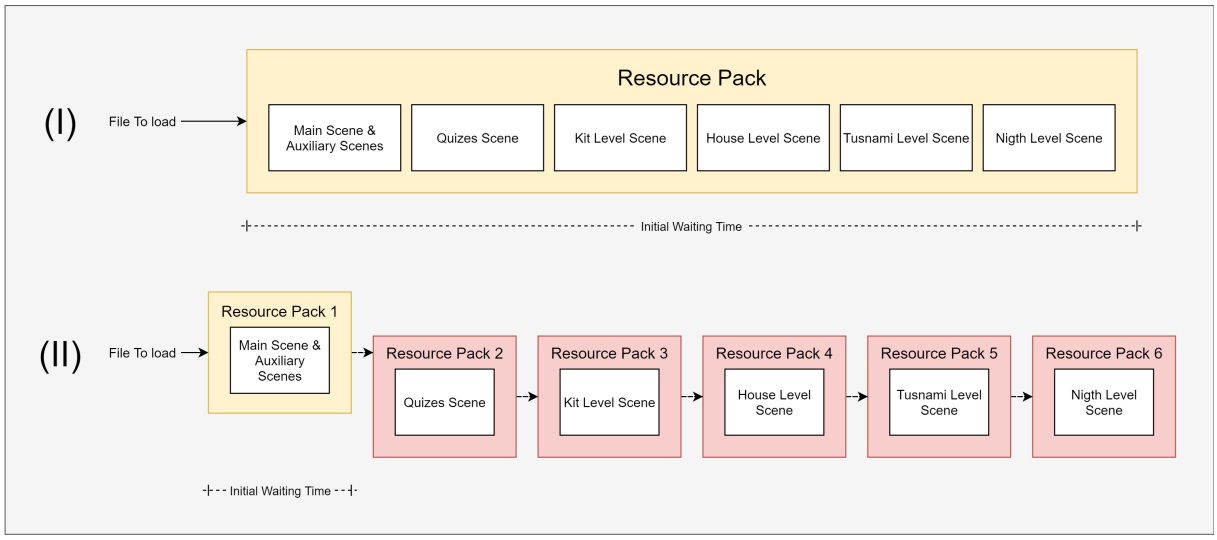

Figure 4.14: Scheme that demonstrates the difference between loading the entire data packet (I) versus loading in smaller blocks (II).

In order to be able to start the testing phase while this problem was resolved, a temporary solution was found to prevent the player from leaving the game before it even started. This solution included integrating a small mini-game at the time of loading to entertain the player while he waits for the game to start (see Figure 4.15). This solution is not very common in the gaming industry due to the fact that it was patented by Namco for twenty years and ended five years ago in 2015.

In order to minimize the loading time and remove the mini-game from the beginning, we have chosen to reduce the size of the images and audio clips as much as possible without compromising their quality. In this way, it was possible to decrease the size of the resource pack by about fifty percent ($\approx$ 60MB). which drastically reduced the loading time of the game.

Although the loading time now has an acceptable value, that no longer justifies the mini-game that appears during loading (when running on newer computers), this time can suffer a considerable increase on older computers. This is problematic since the computers present in most schools that have been visited since the beginning of this project have older computers. For this reason, we have chosen to keep the mini-game at the beginning, due to the fact that schools are the main target of our game and it is necessary to adapt it to their reality. This solution with a mini-game at the beginning of the game had a very good performance because the children that tried the game loved the mini-game.

4.8 Background Music

During the execution of the game, the music jammed during the transition between scenes which led the player to abandon the game, since he thought the game crashed. What happened was that the

Figure 4.15: Game preload screen with the mini game (i.e., the snake game) that was added in order to enternaint the players while the main game loads.

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.

To solve this problem, multi-threading was used, one thread to run the background music and the other to load the scenes. In this way, the loading of the scenes ceases to conflict with the reproduction since they run on separate threads. This thread system is implemented and works correctly, however, it was disabled for the web version since Godot threads are not available for HTML5[6]. One day that this feature is available, it will be enough to just enable the functionality.

For the web version, 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.

[6] https://docs.godotengine.org/en/stable/getting_started/workflow/export/exporting_for_web.html#unimplemented-functionality

5

Game Monitoring

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This chapter 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 initial idea was to carry out the assessment personally, which was not possible considering the pandemic caused by SARS-CoV-2, and for this reason, the assessment was carried out remotely, as we will see in Chapter 6. However, since a system to capture the needed data was not available, there was a big loss of information with this study.

The developed tooling capture, real-time, data from the player, registering all their actions. With this system, it is also 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.

5.1 Database

Before we start talking about the mechanisms used to carry out the monitoring of the game from a distance, it is necessary to talk a little about the database that will be used for all the metrics of supervision. The database used is an unlimited MySQL database, which is integrated into the Hostinger (i.e., host service where the site is)) package. In this database, three tables were created, which will be available for:

- Player identification;
- Count website accesses;
- Collect player logs;

From now on, all accesses that are described to the database, be the connection requests, queries, or insertions, will be performed through the PHP Data Objects (PDO) extension that defines light and consistent interface for accessing databases in PHP. It also provides a data-access abstraction layer, which means that, regardless of which database is being used, the same functions are used to issue queries and fetch data[1].

5.2 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. The first attempt to try to identify the user was to use their IP address. As soon as the player entered the website of the game, his IP

[1] https://www.php.net/manual/en/intro.pdo.php

was captured and stored. The idea was for this IP to be stored, permanently, so that it can be consulted and used to identify the player whenever necessary. However, this game was developed in order to be used in a classroom situation where students play simultaneously on several computers connected to the same network.

This detail of several players being connected to the same network means that a lot of data is lost using the IP as the identifier of the player, since all students in the classroom will have the same IP address, given that the public IP of all players devices connected to the same network is defined at the output of the router and is the same for all devices that are connected to it. Thus, if there are thirty students playing in a class, for our system there will be only one. The solution to this problem was to set aside the use of IPs and opt for a system of cookies that works identically.

As soon as the user enters the game, a random number is generated and stored in the database to ensure that each device has its own unique ID. If the number already exists, another one is generated until a number is created that does not yet exist in the database. Once created, the ID is stored in a cookie that is valid for two years, however, each time the player returns to the website is added to the time necessary to reestablish the two years again.

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. Despite this, this method will be used to identify the player in Sections 5.3 and 5.4.

5.3 Data Capture

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

Although this procedure worked well in controlled environments, this solution did not behave as intended in other environments since the file was saved at the end of the game (i.e., it did not contemplate the cases where the player left the game before reaching the end, or the cases where the player repeated the game after finishing). In order to address this problem, log capture settings of Godot were disabled and HyperText Transfer Protocol (HTTP) requests were used. In this new solution, the file is created directly in the Hostinger file manager and is written when HTTP request messages are receiving during the execution of the game.

However, since Hostinger has a file storage limit, this method was mainly used in the thorough testing and development phase of the game. Unfortunately, with the impossibility of conducting face-to-face tests, as initially intended, it led to the realization of an online test, as we will see in Chapter 6.

ID	Date 1	Time	log
8669	2020-09-02	03:08:36	"-- Start game --"
8669	2020-09-02	03:08:46	"Character: terramota"
8669	2020-09-02	03:08:53	"-- INTRO LEVEL --"
8669	2020-09-02	03:09:14	"-- KIT LEVEL --"
8669	2020-09-02	03:09:54	"Whistle, Radio, Battery, Flash, Can, Bottle, "
8669	2020-09-02	03:09:54	"-- FINISH KIT LEVEL --"
8669	2020-09-02	03:10:00	"-- HOUSE LEVEL --"
8669	2020-09-02	03:10:40	"HIDDEN UNDER THEBED"
8669	2020-09-02	03:11:58	"DIED ON THE GAS"
8669	2020-09-02	03:12:21	"HIDDEN UNDER THEBED"
8669	2020-09-02	03:13:36	"-- FINISH HOUSE LEVEL --"

Figure 5.1: Part of the database table after a player session.

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 continues to be carried out via an HTTP request, but storage is no longer done through files but 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. This data is collected whenever the player loses and where he loses, whenever he uses an item in the kit, he collects information about the strategies used by the player to escape (e.g., where he hides during the earthquake), and also the timestamp in which each action is performed. There is a specifiable sequence for the completion of each level, with more or less variance, so it is possible to perceive any interruption in the expected timeline that may be associated with a bug or some phase that is too difficult or too easy.

5.3.1 HTTP Request - Server Side

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

Every time a request is received, the read-only stream, ***file_get_contents('php://input')***, is used, which allows you to read raw data from the body of the request[2] to retrieve the message and send it via

[2] https://www.php.net/manual/en/wrappers.php.php

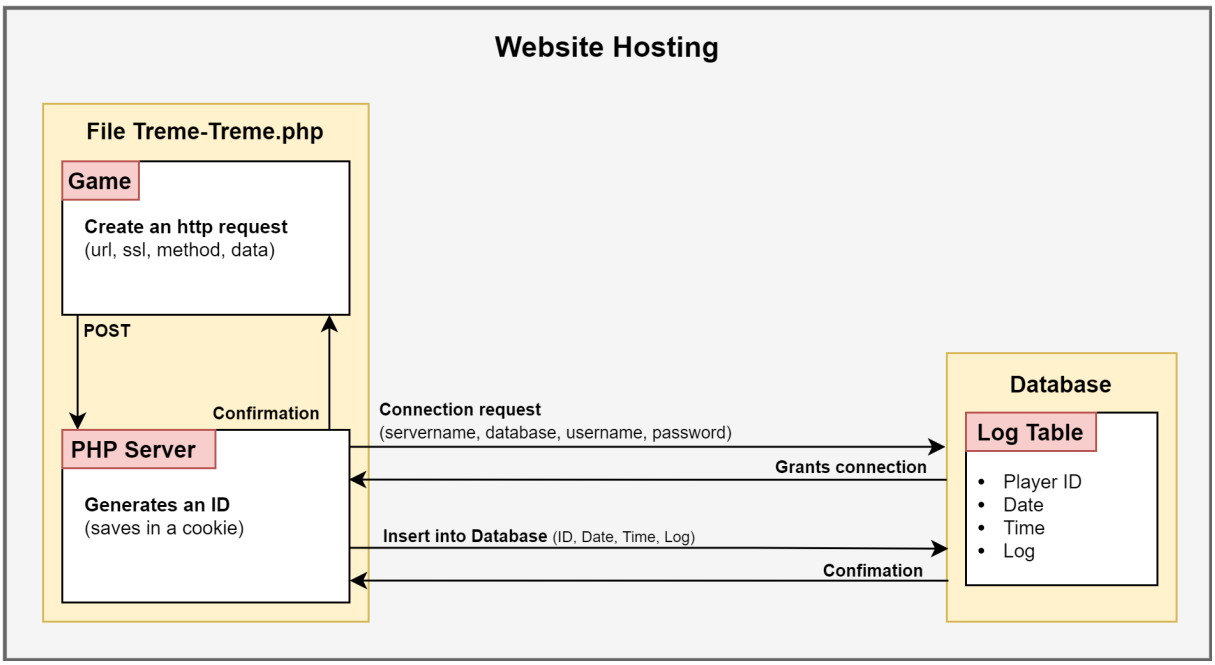

Figure 5.2: Scheme that summarizes the operation of the data exchange system between the website and the database.

the following SQL query:

$$INSERT\ INTO\ Log\_tabel\ (ID, String)\ VALUES\ ('id','msg')$$

to the database that records the time and day the message was received (See Figure 5.1 and 5.2).

5.3.2 HTTP Request - User Side

In this document, the mechanisms that the server has to retrieve the received message have already been described, but for this message, change happens, it is necessary that the client-side has also some mechanisms for sending the message. Whenever an event (that is considered interesting for analysis) happens, an HTTPRequest node, that is placed in the scene tree, is created, this receives the message to be sent in a string format, and then converts 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 argument the content of the message and, the HTTP POST method identifier (**METHOD_POST**) 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.

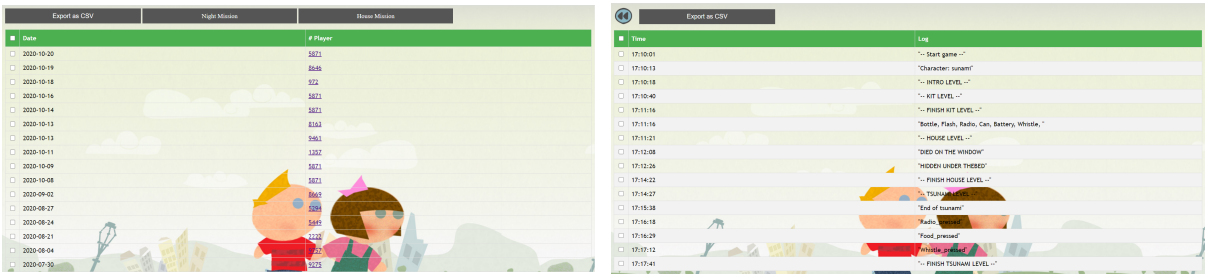

Figure 5.3: Web page with tables representing the collected data (Data, ID) and (ID, Log).

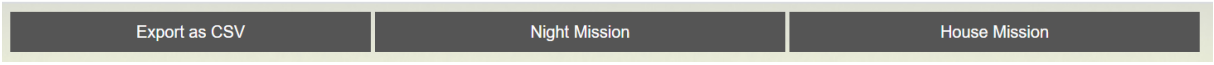

Figure 5.4: Actions available on the results page, download data in csv version for post processing, and buttons to access summaries for each level.

5.4 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 an ID and password has been developed (so that it is only accessed by the people in charge of the project), providing the representation of the data in a simplified and easily accessible way. The PHP server starts by connecting to the database so that it can then execute the following query:

$$SELECT\ DISTINCT(ID),\ Date\ FROM\ Log\_table\ ORDER\ BY\ Date\ DESC$$

which fetches from the table of logs all the different entries in the column of the ID of the player and respective date, in order to list them in a table, in descending order of date (i.e., from the most recent to the oldest). Through this table, it is possible to monitor the history of any player on each day, just select an ID on the desired date and a new table is loaded with the history of the selected player on that day.

As soon as the identifier in the first table is selected, two variables are created, one that stores the selected ID and another that keeps the date corresponding to that ID, which is passed through the website URL (e.g., *results.php?**date=2020-10-19&id=8646***).

The new table is filled with the search result in the database with the query:

$$SELECT\ Time,\ log\ FROM\ Log\_table\ WHERE\ ID\ =\ id\ AND\ Date\ =\ date$$

where the identifier and date are obtained through the value of the variables that are in the URL. This query selects all entries in the Time and Log columns, whose ID and date correspond to those previously selected.

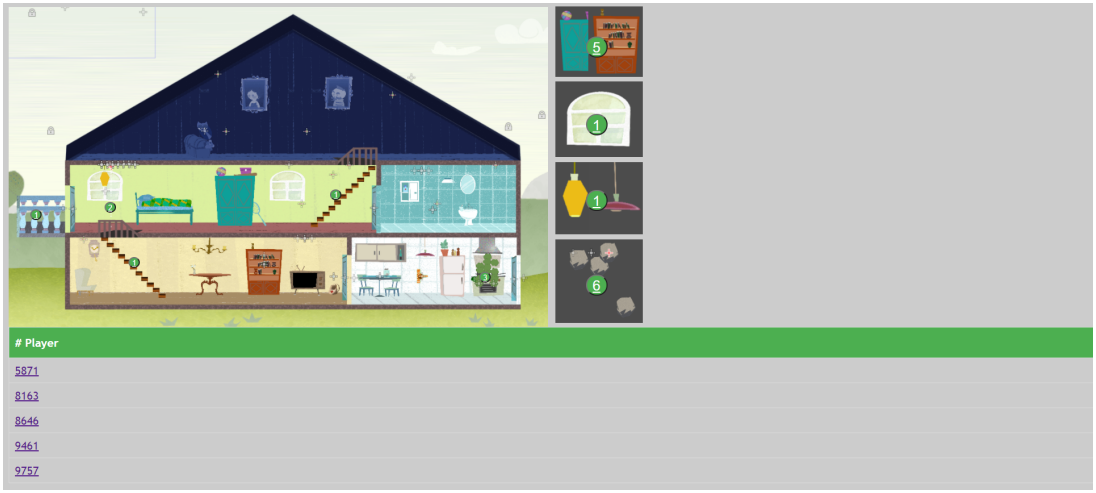

Figure 5.5: Summary page of main events at the House Mission level.

Figure 5.6: Summary page of main events at the Night Mission level.

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. To facilitate obtaining these statistics, the three buttons in the Figure 5.4 were added

By clicking on the button *HouseMission* or *NightMission* the user is redirected to the pages that are represented in the Figure 5.5 and 5.6 respectively, where are summarized the number of deaths that occurred in each place where it is possible to lose, within each of the two levels.

The values are obtained through the database where, for each location, the count of all IDs of players that lost in that place is counted. This information can be found on the map of the game in button format that allows, when clicked, to list, in a table, which players have lost in that area. In this table, it is still possible to select one of these IDs to check the entire history of the player that day. The information contained in these two pages is the summary of the losses in the game that will allow you to check if there are parts in the game that are either very difficult (i.e., if the number of deaths is high), or very easy (i.e., if the number of deaths is low).

Each person responsible for the project may want to obtain different graphs and statistics and for that, he needs to obtain the data in a way that he can work with them. To facilitate this process, the button *Export as CSV file* was added, which allows the user to download a file in Comma-Separated Values (CSV) format (i.e., an unformatted file format in which the values are separated by commas, delimited

Figure 5.7: Main menu of the Treme-Treme website.

by quotes and, where, each row has a different record[3]) of the rows selected in the table that can be opened in any spreadsheet software, thus facilitating the obtaining of statistics.

5.5 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 and, 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 (represented in Figure 5.7) a new visit was counted;
- If the same visitor accessed the site several times in a short period of time (for example 2 in 2 minutes) all accesses were counted;
- It did not allow to know which devices/browsers were accessed from;
- As it was merely a number that increased, it did not allow the elaboration of statistics such as the retention rate of the site, the average time of interaction among others;

In an attempt to solve this problem, the script that counted visits was replaced by a new counter from the Web Contadores[4] service. Web Contadores is a website that offers a free visit counter service that does not need to be associated with any email address. This is a service that not only counts the number of accesses but also offers detailed statistics on accesses. This solution allowed not only to solve all the aforementioned problems but also made it possible to obtain new parameters such as:

[3] https://bit.ly/3kkoZw2
[4] www.webcontadores.com

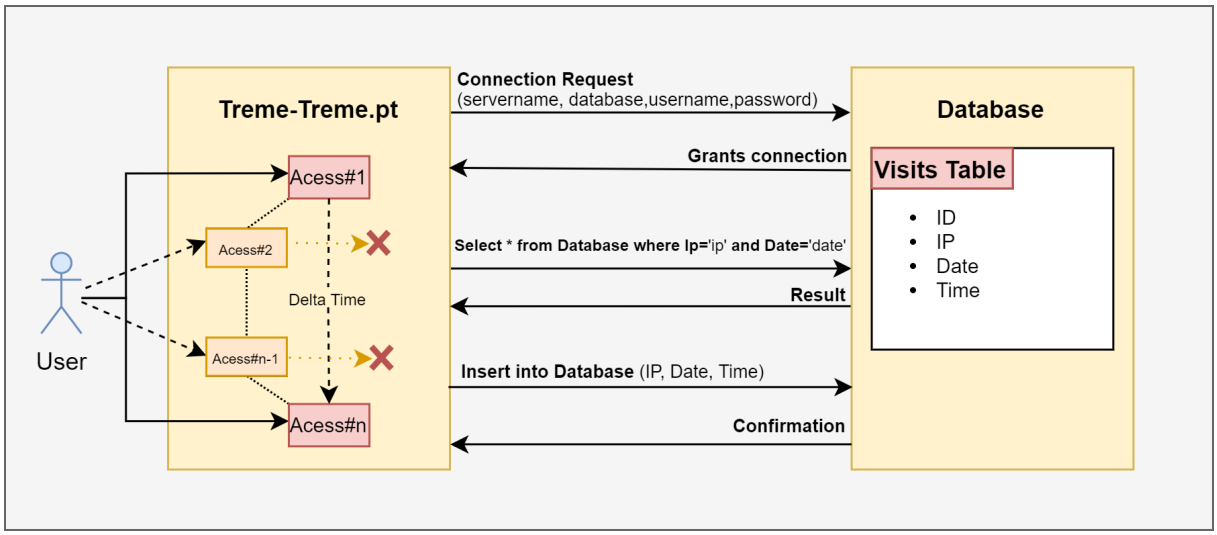

Figure 5.8: Example diagram of how the access count script works.

- The city/country from which access was made;
- The time the access was made;
- Live monitoring of website accesses;

This solution also had as a positive factor the fact that it would be possible to configure the initial value of the meter thus allowing to maintain the historical past visits. However, even resolving all the initial problems, this solution raised an even bigger problem since anyone can access the statistics page, since, as already mentioned, this service does not need to be associated with any email address or ID.

The new solution arranged to solve all the problems involved the use of Google Analytics, a free service from Google that, associated with an email and a website, generates a script to capture visitor statistics. This alternative is similar to the previous one, having all the metrics of Web Contadores and as it is associated with email, it is not published for access by all users. With this solution, it is also possible to add employees to the statistics page so that they too can access the data. And since all solutions have their pros and cons, this is no exception:

- 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;
- Google analytics does not display the number of visitors to the site. Although this is not a big problem, in this project 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 three hypotheses previously described. This solution maintains the account in Google Analytics to consult the statistics,

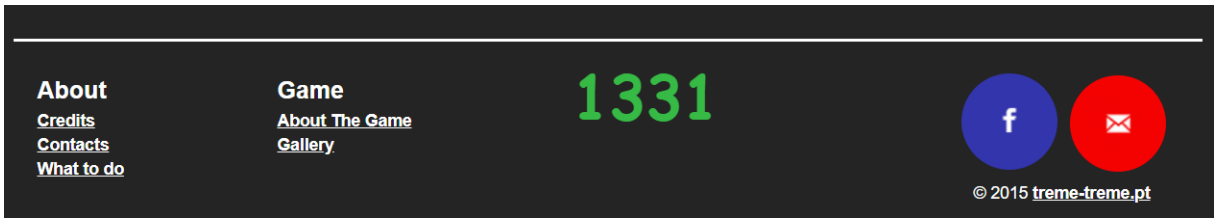

Figure 5.9: Visit counter of Treme-Treme website

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 5.8).

The concept consists of using a table in a mySQL database with four columns:

- Index, an **AUTO_INCREMENT** variable;
- Visitor ID;
- Date of visit;
- Time of visit;

At each access to the website, the script checks the table and verifies that the ID of the user who is accessing it has already been registered today. If the IP has not yet been registered, the day, time, and ID are added to a new row in the table. If the ID has already been added, it is checked at what time the last access was made and if the time interval between accesses is greater than the delta time stipulated, the visit is counted, otherwise, it is ignored

As the only requirements that are relevant for counting are the day itself, we eliminate all rows from the table that do not correspond to the current day with the following query:

$$DELETE\ FROM\ Visits\_table\ WHERE\ Date\ != \ 'current\_date'$$

This way it is possible to decrease the time of each search in the table and also the necessary memory.

When eliminating the accesses of the previous days, the counting is ensured by the Index column since it is an **AUTO_INCREMENT** column, increasing its value by one unit for each insertion in the table. In this way, we can obtain the total number of visits through the SQL query:

$$SELECT\ \ FROM\ Visits\_table\ ORDER\ BY\ ID\ DESC\ LIMIT\ 1$$

The table is sorted in descending order by the Index column, causing the first row of the table to contain the current value of the total number of visits (see Figure 5.9). In this way, we obtained a solution that maintains the statistics of Google Analytics, past history, and even data privacy.

6

Evaluation

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This chapter discusses the techniques used to evaluate both the performance of the game and the fulfillment of the proposed educational objectives. Initially, as already mentioned throughout this document, 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 2020. This event meant that the tests that were expected to be carried out in schools had to be adapted and carried out remotely. Initially, it was proposed to carry out two tests, one first in order to assess the performance of the game as well as to detect and correct game failures. The second would have as its goal the same objectives as the first test, and also evaluate the knowledge acquired during the game and their retention. These two assessments will be described in this chapter

6.1 Online Evaluation

The first evaluation that was carried out had the objective of testing the first ready version of the game and it was carried out with two classes from the Instituto para o Desenvolvimento Educativo Integrado na Acção - IDEIA in Tires, one from the first and the other from the third year of schooling, with ages between six and seven years old for the first class and between seven and eight for the second. The two classes counted, in total, twenty-seven students, who participated in the tests from June 16 to June 22, 2020 that 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;

Thus, the link to the game was made available as a daily task in google classroom so that all students had simultaneous access, and at the end, they would have to answer a gameplay questionnaire slightly adapted to the age of the children. This questionnaire served to verify if the player reached the flow state and was developed in a way that was not exhaustive (since it is not easy to keep the attention of the children when answering questionnaires), and for this reason, it was necessary to give up some questions to keep the questionnaire reduced. For this, the questions we considered most important were selected and that provide us with more information on whether the flow state may or may not be close to being reached (i.e., we kept only the issues that directly interfere with the immersion of the player and address the topics defined in the section refsec:teories). The final questionnaire totaled ten questions about gameplay and eventual bugs that may have happened. The selected questions can be consulted on the Table 6.1.

	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 6.1: Questions list of the gameplay questionnaire.

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, was calculated a Cronbach's alpha coefficient to studies the correlation between the answers. If α is bigger than 0.7 is acceptable to say that there is a correlation between the questions and we can treat them as one. In this test, we need to prove that there is a correlation between the seven first question of the questionnaire with the exception of the second (*ii* in table 6.1) because we need to deal with her in a different way (this need will be explained later in this section).

The result of α can be seen on the Table 6.3 where is verified that the α-value was 0.797 which is larger than 0.7 and, for this, we can say that exists a correlation and we can process the result together.

After certificated that the questions are correlated, we could carry out a T-Student hypothesis test fusing the questions (i.e., working as they were only one). So a T-Student hypothesis test was performed with the average of the first six questions (i.e., the first seven questions except for the *ii*) at a level of significance of 5% to verify if the hypothesis that assumes that if the average of the answers of 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).

For this we formulated two hypotheses, the null hypothesis (H0) that assumes that the average is equal to three and the hypothesis to be tested (H1), the average is bigger than three:

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

The results can be seen in the Table 6.3, where it is possible to verify that the p-value was 0.0162, a very significant value because is smaller than 0.05 and that allows us to discard H0 and accept H1. So, if the difficulty of the game is adjusted to the skills of the children, we can believe that flow state may be being reached for the majority of players.

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

Table 6.2: Results of answers from the players of the first seven questions of the gameplay questionnaire.

α	0.797
X	3.636
p-value	0.0162

Table 6.3: Results of statistic calculations, with the Table 6.2 results, of Cronbach's alpha and p-value of hypothesis T-Student test (without question *ii*).

As we saw before, question *ii*, the question of difficulty, was ignored and it was because in this case, the ideal answer was not five but three. This is due to the fact that the game should be neither too easy (one) nor too difficult (five) and this is the reason to not encompass this question on the others.

The ideal results for this test will be the average stay between four and two, so, in this question, we formulate two T-Students tests. The first has as hypotheses:

- H0: $\mu = 2$;
- H1: $\mu > 2$;

And the second:

- H0: $\mu = 4$;
- H1: $\mu < 4$;

The first T-student test serves to see if the average is larger than two. The p-value calculated during the test was 0.000000023 that is much smaller than 0.05, so we accept H1. For the second we got a p-value of 0.048 that also is smaller than 0.05 and we reject H0. So as we accept H1: $\mu > 2$ and H1: $\mu < 4$ we have $2 < \text{average} < 4$ and we can believe that the difficulty of the game is appropriate.

So with the global average bigger than three and the difficulty average between two and four (both in the ideal intervals) we can believe that the flow state can be being reached.

However, in this study were happened some unforeseen. When we proposed this study, it was to be presential. So, when we needed to do this test in an online way we knew that would imply some risks, beginning for we did not have a remote system to monitor the players (the system only arise as a consequence of this study).

Placing children in their homes to play brought us some problems in evaluating the results, as there was a suspicion that the questionnaires, at least those of the youngest children, may have been answered by the adults, and if the adults answered the questionnaires, nothing guarantees us that they have not helped players to overcome obstacles.

Another problem that was 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» and due to the fact that we did not have a control questions because the questionnaire had to be as smaller as possible we can not validate answers. For this reason, we do not have assurances about the data.

The fact that we put children to answer online gameplay questionnaires, where concepts such as immersion and concentration are addressed (concepts that are not internalized by children), may have answers that not mirroring the real feelings of the children. In the construction of the evaluation questionnaire for the second evaluation, the Ph.D. student in Education warned us that in questions **(iii)**, **(iv)** and **(vi)** of the section 6.1, respondents may not have answered what they really felt given, because for them the questions may not have the connotation that we give them.

To add to all these setbacks that arose, one class should have played the game on June 16 and the other on June 17 and answered the questionnaire immediately after, but, this did not happen, the players played between days 16 and 19 (i.e., causing the players to not have played in simultaneous), making possible the interchanging of information with the others that already played. In addition, there is the fact that many of the respondents did not answer the gameplay questionnaire on the same day that they played, as seen in the plot in Figure 6.1 where it is possible to see that only about 33% of players answered the questionnaire on the same day that played the game, that makes the concepts that for them are already abstract, even more abstract. This detail makes the results unfeasible since the players have to resort to remembering what happened in the past which may not represent the real situation. We knew beforehand that this could happen, but since there were no other alternatives due to the closure of face-to-face education, we decided to take the risk.

Bearing in mind that this online assessment was not intended to test knowledge in the short and long term since no control group was selected. However, both teachers decided to carry out a small knowledge questionnaire. The tests were different for the two classes, and although the test averages were 98% for the youngest and 81% for the oldest, we cannot attribute good results exclusively to the game (i.e., there was no control group, meaning we do not know what the previous knowledge of the players was, and what was the improvement compared to standard lessons).

6.2 Pedagogical Evaluation

In the previous evaluation, we found some problems that could compromise the player experience, and that needed to be resolved before began this second test. After the modifications to the game were completed, a study with the intention of evaluating the didactic part of the game was created.

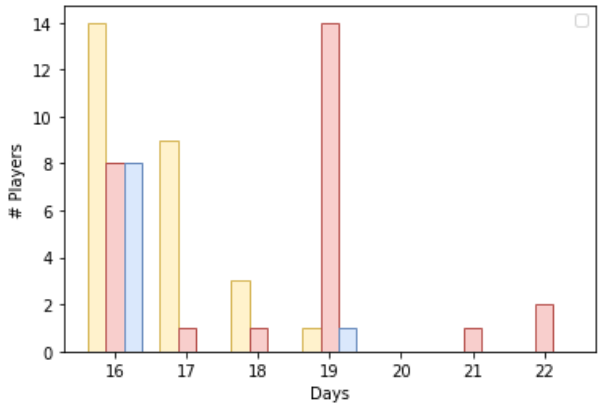

Figure 6.1: Day in that the players play the game (yellow bars) vs day in that the players answered the gameplay questionnaire (pink bars) vs the players that answered the questionnaire on the same day that played (blue bars).

This study was elaborated with the help of a psychologist from the Group of AI for People and Society (GAIPS) and a Ph.D. student in education at the Instituto Universitário de Ciências Psicológicas, Sociais e da Vida (ISPA), and only evaluates the didactic part of the game.

The test needed to be executed with the most rigor and should not encounter the problems that were found in the online assessment previously described (i.e., the new study was designed to be carried out in person in order to avoid taking the same risks that the last study had).

This evaluation must be carried out with a control condition, therefore, we needed two classes of students from the same school year, preferably from the third or fourth year, and if possible from the same school or the same social context.

This time, the objective is no longer to find 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 that we can see in the schema of figure 6.2.

- 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.

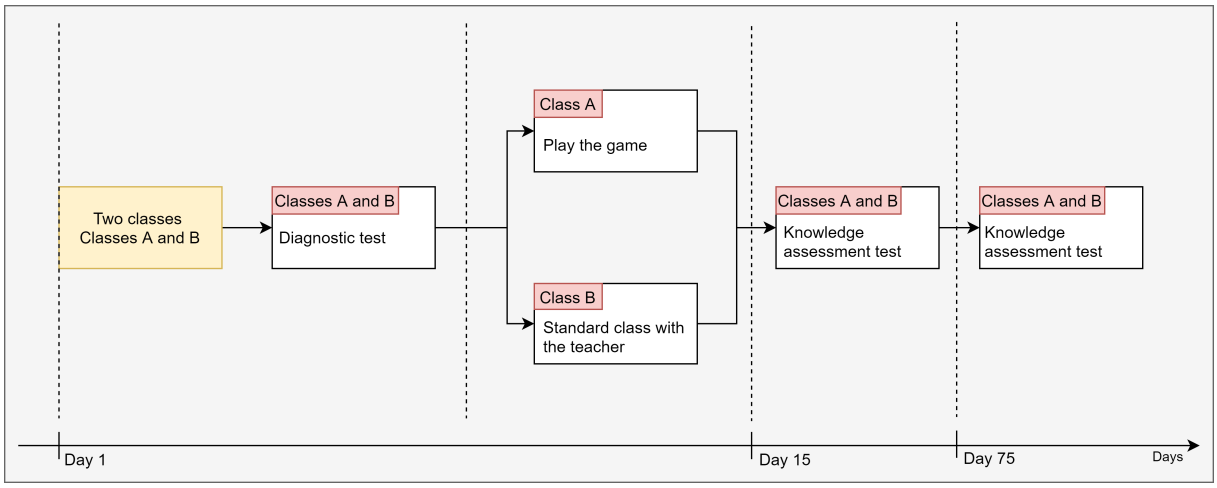

Figure 6.2: Outline that summarizes the planning of the study on learning that lasts 75 days.

Phase 1 served to ascertain the knowledge that the study participants already had and understand whether or not they can iterate in the study. All students who are going to participate must take this test at the same time, and it can be done on the same day that Phase 2 of the study is carried out, as long as it is done before.

After evaluating the results of the diagnostic tests carried out in Phase 1, if the students of both classes are qualified for the next step (i.e., they do not have a lot of previous knowledge), Phase 2 could start, otherwise, the study is interrupted and it is necessary to start it again with another study group. During the execution of the game, it is important that at least one person responsible for the study is supervising the children in order to be able to solve any problem that may arise and to be able to assess the state of mind of the player to understand if the immersion objectives are being achieved. In Phase 2, one class will play Treme-Treme and the other will be the control group (i.e., it will not play the game), but will attend a standard lesson, with their teacher, that addresses the same content on the topic.

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

Fifteen days after the end of Phase 2, both classes must complete 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.

It is true that it is not possible for us to prevent children from talking about the experience between Phases 2, 3, and 4, however, it is essential that both classes carry out the activities of all phases simultaneously, in order to try to avoid crossing as much as possible of information.

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 6.4: Game retention rate by levels

This study should be designed to start when schools reopened in September-October, at that time, and during the months that followed, we came into contact with countless schools that, due to the pandemic evolution and the contingency measures applied in schools, ended up denying us the study, which delayed this process. So 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.

The evaluation already concluded the first two phases and was performed by two classes, one of the fourth and the other of the third year of schooling of the Arco-Iris school in Olivais. However, the results of this study will have to be presented in the future

6.3 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 (i.e., since it is published online on the website and continues to receive visits), through the data collection system previous described that provides enough data about the game to extract meaningful information. Through this information, it is possible to verify if the level of difficulty of each level is or not suitable, and which places of the game are more problematic, together with the game retention.

From the data of the capture mechanism of December 22nd summarized in Table 6.4 where were analyzed 910 logs of players who started the game for the first time, we can see that of theses 910 logs, only 833 started the first level (Emergency Kit), and just 271 completed the last level of the game (Night Mission), which corresponds to a loss of more than 60% of the players. The level that presented the highest rate of loss of players was that of House Mission, where 264 users did not complete the level and 20 abandoned the game after completing it, which corresponds to just over 31% of the players who started this 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.

It would be expected that the loss rate of the players would be lower in the level with the larger preference, but that did not happen. As it is possible to verify in the Table 6.5, the two favorites levels, House and Night Missions, correspond in the Table 6.4 to the levels with the biggest loss rate.

Emergency Kit	House Mission	Tsunami Mission	Night Mission	Quizzes
1	8	7	10	1

Table 6.5: this table shows the number of players who liked a certain level more.

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

Table 6.6: Performance in stars of players in the quizzes levels.

Level	Furniture	Rocks	Balcony	Stairs	Gas	Windows	Lamps	Eletric Wire	Total	#Players
House Mission	749	1506	60	500	431	383	304	731	4664	1433

Level	Wave	Total	#Players
Tsunami Mission	182	182	898

Level	Buildings	Holes	Eletric Poles	Total	#Players
Night Mission	915	920	915	2750	791

Table 6.7: Number of deaths in all places where it is possible to lose at each level

The presented information demonstrates that, or the data collected in the online test are incorrect, or that there may be a difficulty above the desired in some of the levels, as is the case of House Mission where each player loses on average, approximately, four times (see Figure 6.3). As we can see in Table 6.7 the House Mission sums a total of 4664 death in only 1433 games which implies that each player loses 3.25 times. Bearing in mind that the level is short and has only three distinct challenges, this number represents that on average, each player loses once more than the proposed challenges, when added to the number of times he may have lost in the previous level, can lead to abandoning the game. In the case of Night Mission, even though each player died 3.48 times (i.e., more than in House Mission Level), this level is longest than the House Mission and has more challenges which decrease the leave rate of the game. It is important to note that the Tsunami level, which has one of the lower leave game rates is the level with fewer deaths, with an average of 0.2 deaths per player.

With regard to learning, although it was not possible to perform the test in a timely manner, from the data collected during the interactions, it is possible to observe (see Table 6.6) that out of 396 users who took the questionnaires for the first time, 101 obtained one star, 156 two stars and 139 achieved the theses stars, which results in an average just over two. However we do not have a way of knowing if this knowledge was acquired with the game or if it was already with the players (or even a mixture of both).

Although we have a high loss rate of players this may not mean that there is something wrong with the game, due to the fact wich these events are quite frequent in the industry, in games that are already in the market, as is possible to verify in steam charts website[1]. To verify this is necessary to realize another gameplay test in order to confirm if the loss rate is due to the fact of losing immersion.

6.4 Evaluation on Different Devices and Browsers

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:

[1] https://steamcharts.com/

Figure 6.3: 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.

- As part of the *Explica-me como se tivesse 5 anos* project, created by Instituto Superior Técnico[2], and the project A Terra Treme from National Civil Protection[3], live events that gave to the website more than 1.700 accesses, which allowed us to evaluate the performance of the game on different devices and browsers. During that busy week, the data capture system worked as expected and there were no problems associated with devices and/or browsers.

- The online evaluation described in Chapter 6.1 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, the questionnaire to which the children answered had space for them to report any problems that may have occurred, where only three answer 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 Civil Protection *A Terra Treme* project was 140 users, while the number of uninstallations was of 11 (7%).

[2] https://explicame.tecnico.ulisboa.pt
[3] http://www.aterratreme.pt/

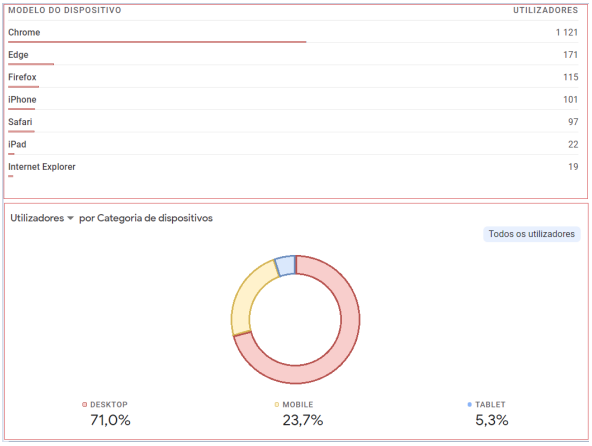

Figure 6.4: The different devices that are used to play Treme-Treme.

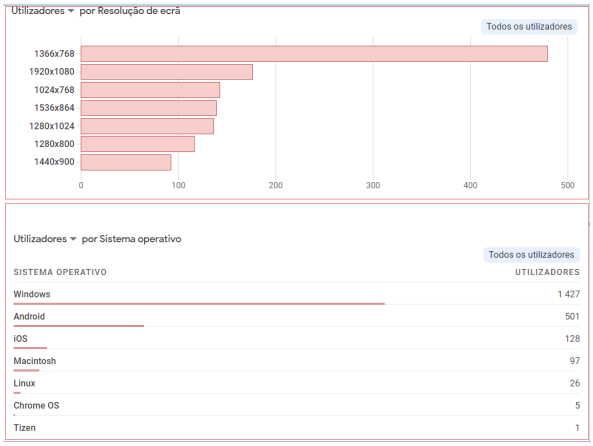

Figure 6.5: The different screen resolutions and operating systems that are used to play.

Through Google Analytics it is possible to see what devices and browsers were most used by the users (see Figures 6.4 and 6.5) 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).

7

Conclusion and Future Work

Contents

7.1 Future Work 67

7.1 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**: As we saw in Chapter 6.2 the evaluation cannot be concluded for reasons unrelated to the project. It is important that this evaluation is finish so that conclusions can be drawn about whether the game meets the proposed objectives. The entire protocol has already been carried out and described in Chapter 6, the assessment test is attached. It is only necessary to execute it, evaluate the results, and draw conclusions.
- **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 and verify if the loss rate is due to the fact of losing immersion.
- **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**: Considering the simple case that a player who gets a star the first time he answers the questionnaire, two on the second and three on the third, in order to the questions not repeat at all, would require nine questions (i.e., three for each try). Now, each level of questions had only six distinct questions, it would be interesting to increase the number of questions so that the range of acquired information increases.
- **Add more languages**: The number of languages should be expanded, adding languages from countries with high seismic activity such as Japanese and Indonesian. Japan and Indonesia are often rocked by earthquakes and can be a potential niche for our game.
- **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.

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Annex

Estudo sobre o Treme-Treme

Hipótese:

O jogo do Treme-Treme produz melhores resultados de aprendizagem sobre terramotos e sismos do que uma aula tradicional sobre o mesmo tema.

Objetivo:

O objetivo deste estudo é comprovar a hipótese mencionada anteriormente, isto é, tentar verificar se os resultados obtidos por crianças que jogaram o jogo, são superiores aos obtidos por crianças que não jogaram quando testados sobre o assunto quer a curto como a longo prazo.

Procedimento:

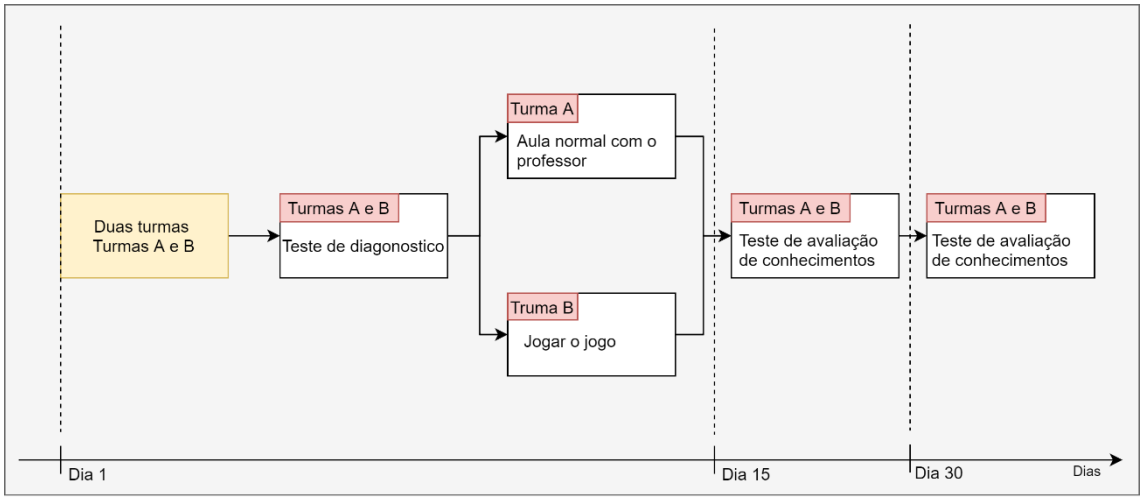
Para este estudo são necessárias duas turmas do mesmo ano escolar (idealmente terceiro ou quarto ano) Daqui para a frente as turmas serão denominadas como Turma A e Turma B.

Os alunos de ambas as turmas (A e B) devem ser submetidos a uma prova de diagnóstico que permita avaliar os conhecimentos que as crianças já possuem.

Depois de realizarem o teste, a Turma A deve iniciar uma aula tradicional sobre terramotos e tsunamis com um(a) professor(a). O(A) professor(a) é livre de dar a aula da forma que achar mais pertinente (PowerPoint, ler um livro, dar uma palestra...) desde que abordem todos os temas descritos no protocolo da aula descrito na próxima secção;

A Turma B deve aceder ao site do Treme-Treme (www.treme-treme.pt) e iniciar o jogo de acordo com o dispositivo que estiver a utilizar e jogar sem interferência do(a) professor(a).

Passados quinze dias deve ser realizado, em ambas as turmas, um teste de avaliação de conhecimento que será igual ao teste diagnóstico. O mesmo deve ser repetido um mês após a data da experiência.



A cada aluno deve ser atribuído um código numérico que tem de ser o mesmo em todos os testes.

Abaixo encontra-se uma tabela que irá associar um número a cada aluno. Esta tabela deve ser preenchida na data do teste diagnóstico e deve ser consultada nos testes seguintes de modo a manter sempre o mesmo número.

Turma A

Código do aluno	Nome do aluno
01	
02	
03	
04	
05	
06	
07	
08	
09	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	
21	
22	
23	
24	
25	
26	
27	
28	
29	
30	

Turma B

Código do aluno	Nome do aluno
31	
32	
33	
34	
35	
36	
37	
38	
39	
40	
41	
42	
43	
44	
45	
46	
47	
48	
49	
50	
51	
52	
53	
54	
55	
56	
57	
58	
59	
60	

Exemplo

Código do aluno	Nome do Aluno
324	António
345	

Teste Diagnóstico

Treme-Treme

Bem-vindo ao questionário sobre o Treme-Treme. Aqui poderás mostrar o que aprendeste.

1. Qual é o teu código?
   324
2. O que é um terrAmoto?
   _____

Teste 1

Treme-Treme

Bem-vindo ao questionário sobre o Treme-Treme. Aqui poderás mostrar o que aprendeste.

1. Qual é o teu código?
   324
2. O que é um terrAmoto?
   _____

Teste 2

Treme-Treme

Bem-vindo ao questionário sobre o Treme-Treme. Aqui poderás mostrar o que aprendeste.

1. Qual é o teu código?
   324
2. O que é um terrAmoto?
   _____

Protocolo da Aula:

- Antes do terramoto:
  - Abordar a importância da realização de um Kit de emergência
  - Indicar os itens que se devem ter num kit de emergência (rádio, apito, lanterna, pilhas, comida enlatada, água)
  - Abordar a importância de conhecermos o espaço em que estamos, ou seja, saber que a vibração faz com que os objetos e mobiliário caia, causando ferimentos e perdas

- Durante o terramoto (em casa):
  - Indicar o que devemos fazer quando começa um terramoto
  - Indicar os locais em que nos devemos proteger
  - Indicar os locais dos quais nos devemos manter afastados
  - Indicar o que devemos fazer quando terminar o terramoto
  - Alertar para as réplicas
  - Alertar para os perigos da eletricidade do gás durante o terramoto

- Tsunami:
  - Indicar o que devemos fazer caso estejamos na praia
  - Indicar como chamar ajuda depois do tsunami
  - Explicar a importância do kit de emergência nesta situação

- Pós-Terramoto/Tsunami (na rua)
  - Indicar quais os perigos da rua
    - Prédios que podem cair
    - Postes elétricos
    - Fraturas no chão causados pelo terramoto
    - Etc…
  - Explicar a importância do kit de emergência nesta situação

Teste Diagnóstico e de Avaliação:

Treme-Treme

Bem-vindo ao questionário sobre o Treme-Treme. Aqui poderás mostrar o que aprendeste.

1 Qual é o teu código?

_____

2 O que é um terramoto?

_____

_____

_____

_____

3 O que é um tsunami?

_____

_____

_____

_____

4 Os terramotos...

Assinala todas as opções que achares corretas.

- ☐ provocam danos nas habitações e ferimentos nas pessoas.
- ☐ provocam danos nas habitações, mas não na rua.
- ☐ provocam danos nas estradas, pontes e jardins.
- ☐ provocam danos apenas na rua.

5 Após um terramoto, se estiveres na rua, deves manter a calma e olhar com atenção à tua volta.

Assinala as atitudes corretas.

- ☐ Devo afastar-me dos buracos que se abriram na estrada com o terramoto.
- ☐ Devo aproximar-me de casas para pedir ajuda.
- ☐ Devo ligar o rádio e esperar por instruções.
- ☐ Devo aproximar-me de postes de eletricidade e de candeeiros.

6. Antes de ocorrer um terramoto, o que devemos colocar no nosso Kit de emergência?

Escolhe 6 objetos que devem fazer parte deste Kit

- [ ] Lanterna
- [ ] Brinquedos
- [ ] Pilhas
- [ ] Rádio
- [ ] Apito
- [ ] Água
- [ ] Comida em lata
- [ ] Sumos
- [ ] Comida fresca
- [ ] Consola de jogos

7. Assinala os sítios seguros na casa onde nos podemos proteger durante um terramoto.

Assinala todas as opções que achares corretas.

- [ ] Debaixo da cama.
- [ ] Ao pé de uma janela.
- [ ] Debaixo de uma mesa.
- [ ] Ao lado de um armário

8. Depois de um terramoto devemos estar preparados para uma possível réplica.

Indica 2 atitudes que devemos ter.

- [ ] Ligar o rádio e ficar atento às instruções.
- [ ] Ligar o fogão e cozinhar.
- [ ] Desligar a eletricidade.
- [ ] Mexer nos cabos elétricos.

9. O Kit de emergência deve ser preparado…

Assinala apena 1 opção

- ( ) durante o terramoto
- ( ) antes do terramoto
- ( ) depois do terramoto

10. Após um terramoto, no caso de estares numa praia, o que deves fazer para te proteger?

Assinala apena 1 opção

- ◯ Esperar que o terramoto passe, porque as praias são sítios seguros.
- ◯ Afastar-me da água e correr para um local elevado.
- ◯ Esconder-me debaixo do chapéu de sol.
- ◯ Correr atrás das pessoas, porque elas saberão o que fazer.

11. Pouco tempo antes de um tsunami acontecer…

Assinala apena 1 opção

- ◯ A maré avança de repente, mais do que o normal.
- ◯ A maré recua de repente, mais do que o normal