TÉCNICO LISBOA

Visualising the contribution of whales as a natural solution for climate change

Application with visualizations to raise awareness about the importance of whales to the atmosphere

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Abstract

Every year the growth rate of carbon dioxide in the atmosphere increases, it is common knowledge that this gas is very harmful to our planet and there is an increasing awareness among the population that it is necessary to act to reverse the development course of pollution is taking.

A perspective to solve this problem would be to understand how it will be possible to reduce pollution production, however, this thesis aims to protect a natural mechanism for capturing carbon dioxide from the atmosphere. A International Monetary Fund (IMF) report illustrates how whales could provide a natural solution for climate change [1], explaining that the cetaceans accumulate carbon dioxide in their bodies during their lives and when they die, their carcass sink to seafloor and the carbon inside is incorporated into marine sediments.

A great whale sequestrates 33 tons of CO_2 on average, while a tree absorbs only up to 48 pounds of CO_2. Besides that phytoplankton contributes at least with 50% of oxygen in our atmosphere and whale's waste products contain substances that make the phytoplankton multiply.

Whales capturing tons of CO_2 per year is a "no-tech" solution effective and economically advantageous, preventing and reversing global warming. So protecting and increasing the global whale population could reduce significantly the amount of CO_2 in the atmosphere.

These phenomena are hard to communicate to a wide audience[1] so we tried to transmit the message with the contribution of this thesis using an interactive application to visualize the impact of whales as a natural solution for climate change. This thesis also reports on the development and testing of interactive

[1] According to a survey carried out in the development of this thesis, less than 20% of the population is aware that whales could help to remove carbon dioxide from the atmosphere

3D visualizations that are part of the application.

Keywords

Carbon Dioxide; Whales; Human-Computer Interaction; Visualization; Awareness

Resumo

Todos os anos a taxa de crescimento de dióxido de carbono na atmosfera aumenta, é de conhecimento comum que este gás é bastante nocivo para o nosso planeta e cada vez mais a população está consciente de que é necessário agir para reverter o rumo que o desenvolvimento da poluição está a levar.

Uma perspectiva para resolver este problema seria entender como será possível reduzir a produção de poluição, no entanto, esta tese visa proteger um mecanismo natural de captura de dióxido de carbono da atmosfera. Um relatório recente do Fundo Monetário Internacional ilustra como as baleias podem fornecer uma solução natural para as mudanças climáticas [1], explicando que os cetáceos acumulam dióxido de carbono nos seus corpos durante a vida e quando morrem, a carcaça afunda no mar e o carbono no interior é incorporado nos sedimentos marinhos.

Uma baleia grande sequestra em média 33 toneladas de CO_2, enquanto uma árvore absorve apenas 48 libras de CO_2. Além disso, o fitoplâncton contribui com pelo menos 50% de oxigénio para a atmosfera e os resíduos das baleias contêm substâncias que fazem o fitoplâncton multiplicar-se.

O facto das baleias capturarem toneladas de CO_2 por ano é uma solução "sem tecnologia" eficaz e economicamente vantajosa, prevenindo e revertendo o aquecimento global. Portanto, proteger e aumentar a população global de baleias poderia reduzir significativamente a quantidade de CO_2 na atmosfera.

Estes fenómenos são difíceis de comunicar a um público amplo, por isso tentámos transmitir a mensagem com a contribuição desta tese usando uma aplicação interativa para visualizar o impacto das baleias como uma solução natural para as mudanças climáticas. Esta tese relata também o desenvolvi-

mento e teste de visualizações 3D interativas que são parte da aplicação.

Palavras Chave

Dióxido de Carbono; Baleias; Interação Humano-Computador; Visualização; Consciencialização

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Listings

Acronyms

IMF	International Monetary Fund
VFX	Visual Effects
US	User Interface
RtD	Research through Design
MVP	Minimum Viable Product
CSV	Comma-separated Values
JSON	JavaScript Object Notation
WWF	World Wide Fund
RTA	Retrospective Think Aloud

1

Introduction

Contents

The theme of climate change has influenced the planet in general and as new natural disasters affect humans, even the most skeptical worry about what might be to come. What causes these changes is pollution and the consequent increase of carbon dioxide in the atmosphere, according to the Mauna Loa observatory, the growth rate is continuously rising. [2]

Thus, there are more and more initiatives aimed at removing carbon dioxide through the most varied forms, such as innovative projects and the protection of natural extractors. It is common knowledge that trees store the CO_2 taken from the atmosphere through photosynthesis, what few people know is that whales also play a very important role and each one is equivalent to several trees.

This project aims to make the population aware of the benefits of whales and the dangers to which they are subjected.

Unfortunately, there is a lot of misery in the world, which means that some people only focus on fighting for survival and therefore the concern for the environment is left aside, however in more developed countries where access to smartphones and computers is a reality and practically a basic need is with great interest that we can look at these digital media to convey ideas that can change mindsets.

Taking into account that more than 6.3 million people use smartphones [3], where on average they spend more than 3 hours and that about 88% of the time on apps [4] we can be sure that these platforms are an excellent way to transmit information in an era dominated by technology.

After a long research it was strangely noticed that all the applications that exist about whales and even more generally, applications focused on the environment, are not known to the general public, only the documentaries of streaming apps, such as Netflix, are capable of going viral and creating even momentary waves of awareness.

However, in this project, we will use the attractiveness of an application but transmit the information in a one or two times use platform that can be used in public spaces such as schools, transport stations, or museums.

Visualizations such as films and documentaries have a strong ability to empathize with the viewer (affirmation sustained through a detailed study of the brain while participants watched emotional Hollywood films presented in the book NeuroImage [5]). In this project, the challenge will certainly be greater because we want that the users empathize with a whale and not a human being, which makes the close relationship a little more complex. We have the example of the case of 'A Life on Our Planet', a documentary that manages to humanize the issue of environmental destruction that can often seem distant and somewhat abstract.

This dissertation describes the process of building a technological platform that, to achieve the intended result, must have not only a good performance, a consequence of the choice of code development technology, attention to efficiency and bugs, but also a careful design to give the user best possible experience.

The 3D visualizations simulate some phases of whale life related to the carbon dioxide absorption, the first one represents a humpback whale that migrates from the feeding to the breeding zone, and the second shows the whale pump, the moment when the whale captures the CO_2 and lastly a video about the whale deadfall that reproduces what happens with the mortal remains where the carbon was stored.

That said, the project aims to mix the simplicity and engagement capacity of an app with the possibility of creating empathy through 3D visualizations to make users aware of the benefits of whales and the dangers underlying migrations.

In short, the objective was to expose the theme positively, presenting the advantages of cetaceans while alive, but alerting people to the hazards they are subject to during migrations by focusing on the user-machine communication to raise awareness through an application.

1.1 Goals

This thesis proposes to develop a platform that sensitizes users to the question of whales as a natural carbon dioxide sequester, being an ecological advantage.

The main objective of this project is to take a currently known topic, climate change, together with a strange topic, CO_2 capture by whales, and understand how an interactive application and its 3D visualizations are effective in transmitting knowledge and creating empathy after its usage. That said, it is intended to achieve the following objectives:

- **Explaining the communication of the climate change**

  Taking in account the paper written by Marta Ferreira, designer that help developing the application, with the help of professor Valentina Nisi and Nuno Jardim Nunes [6], we will build our application following a positive framing;

- **Review state of the art in visualizing climate change**

  Analyze major applications and visualizations and identify not only what failed, but also strengths;

- **Produce a platform to communicate visually the impact of whales as a natural solution for climate change**

  Central part of the project that consists of developing an application with an appealing design that allows interaction through and that captures the attention of those who use it so that they manage to retain the essential and become aware after use;

- **Evaluate the impact of interactive visualization**

1.2 Organization of the Document

Chapter 2 provides a detailed study of work related to whales, climate change and environmental disasters, emphasizing applications and visualizations to find good practices to guide us and, on the other hand, show us paths we do not want to follow. In chapter 3, the result that the research among users had before the development of the project is presented. Chapter 4 serves to portray the most important part of the project, the application development process beyond the creation of 3D views that simulate whale paths and the application too. In chapter 5, we find the description of results derived from the use of the platform and, finally, in chapter 6, a conclusion about the project is presented and suggestions for possible improvements.

2

Related Work

Contents

In this chapter, we will analyze a range of applications and short videos, since are responsible for much of the time occupation of human beings who have been seduced by the digital era, that targets environmental issues. There will be an assessment of the strengths and weak points of each application, furthermore short videos' examples and the advantages of presenting themes through video are analyzed, as well as the study of the negative points of each one. In the end, each related work's influence on the development of the project will be explained as well as what makes our project different.

2.1 Mobile applications

The use of smartphones and tablets among students is a rapidly growing trend [7], particularly at the time of lockdown caused by COVID-19. With thousands of apps available on the App Store and Google Play, there is a wide variety to suit students' needs, however, it is a big challenge to develop efficient code and produce a design that fits specific learning requirements. Research [8] about the influence of mobile apps in pedagogy and mobile devices as tools in educational interventions has revealed that the overall effect of using mobile devices in education is better than when using desktop computers since effectively communicating contents and concepts through educational apps reduces the cognitive load on the users with an easy and faster flow of information, according to a study about science learning carried out in a school [9].

After further research [10] it was concluded that smartphone applications aimed at scientific learning had similar designs and functionalities, certainly influenced by previous research and works that were based on the test of scientific knowledge and conceptual understanding of the students and led to formulate recommendations that if followed will be a strong help the success of a project in this area.

Most recently a study [11] found a positive association between academic assistance and the intention to use educational apps during the COVID-19 pandemic because many students depended on educational apps for learning. An interesting fact about this work is that the high school and college students may be looking for more subject-specific content than entertaining content, unlike younger target audiences as proved by previous research [12, 13].

To find some related apps we started with detailed research on the applications market to understand the state of this topic and even to be able to take some kind of inspiration, however it was strange that we came across the lack of a category "Environment" in the *AppStore*, there is only a small highlight, after more than 20 highlights, at the bottom of the Apps tab, about sustainability with 19 apps, of which were analyzed the 2 most similar to our work.

In the case of the *PlayStore*, no highlights or categories on the environment or sustainability were found, so we will restrict ourselves to the *AppStore* apps.

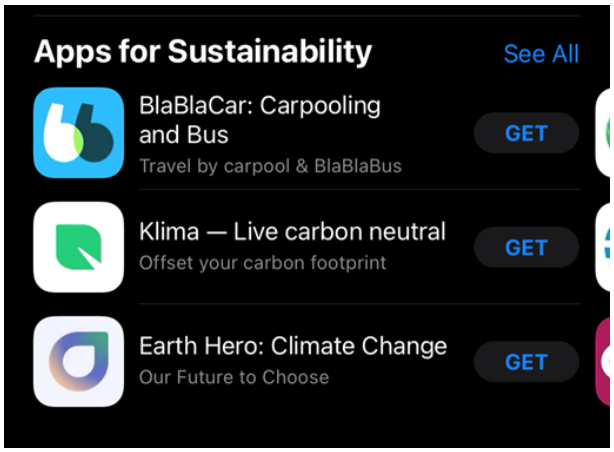

Figure 2.1: App Store Sustainability Section

2.1.1 WWF Together

It starts with a very simple animation that holds the attention followed by onboarding and when we skip it we find a background with a photo of a Panda and a menu with a selector of 16 animals that after choosing what we want takes us on a learning journey about the animal in question.

As expected, we opted for the whale icon and faced a summary that mentions their hazards, then gives us some statistical data about approximate population, habitat, weight and size. The third screen has stunning photos of whales, followed by a screen that lists the threats to which they are subject through an icon and small summaries for each of them (whaling, oil development, bycatch).

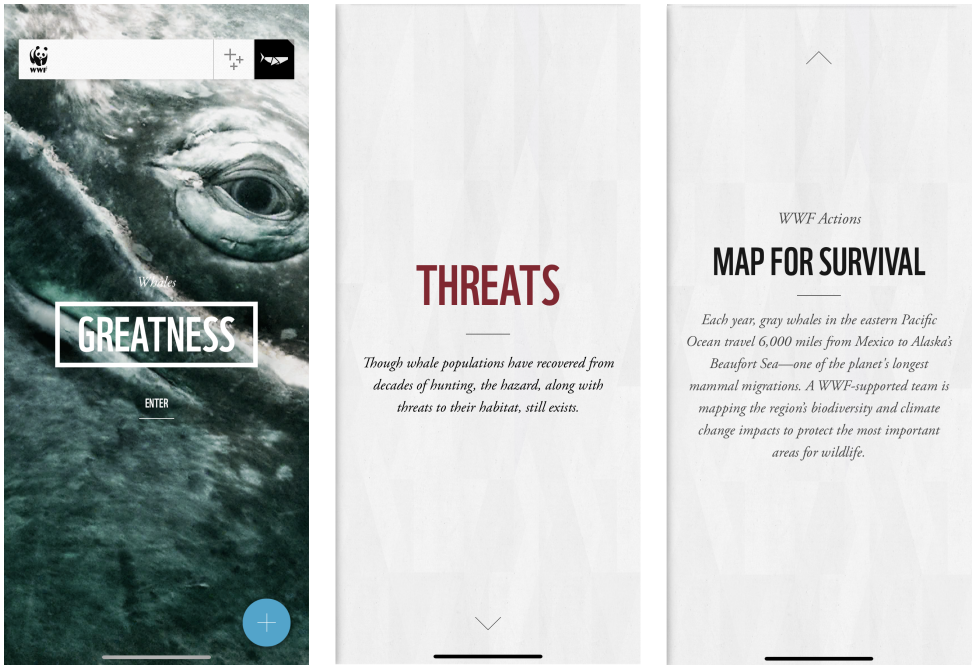

Figure 2.2: Some WWF Together Whale Screens

The fifth screen has a simple and very well-done animation about the sound of a blue whale, as it is “the loudest” on Earth, comparing it to sounds that are familiar to us. Finally, we find a screen that shows us, through a risk scale, the position of the whales and the actions that the *WWF* organization takes to protect this animal.

We chose this app because it is related to animals and when analyzing it we found a differentiated design and a good performance. The information that the application intends to transmit is summarized and easily internalized, no screen has much content, which makes them easy to analyze and because they are interesting, it captivates the user to move on to the next one creating empathy with the cetaceans.

Our application is different from this one, although focused on whales we have another point of view on the subject, explaining how the whales are important to the world and not going into detail about whales and their hazards. In respect of building the platform, we not only developed a more animated design and not so realistic as *WWF Together* but also added some videos to support our message.

2.1.2 Milkywire

Milkywire is a kind of social media and despite being an app that does not target any specific subject, the goal is that the user chooses to learn about several causes (including ocean and whales protection) and support the one or more that they prefer and follow it up.

On this platform, we are introduced by an onboarding, which shows us a home page with a feed of news related to the causes that the user supports, next to a tab where you can explore 6 causes (bees, wildlife, climate change, trees, oceans and cleaning the planet). The third tab has a feed with all the news and the last tab with a user profile.

We decided to explore the cause of the oceans in more depth because it is related to the theme of the thesis.

The first screen, presented in 2.3, has a looped view of a short footage mix of the oceans and the animals that live there and also has a description that addresses the fact that oceans’ phytoplankton is responsible for providing more than 50% of the Earth’s oxygen and absorbing carbon dioxide emissions. It also has short videos with footage of the ocean and accounts of activists who have contact with it and are aware of the problems to raise awareness of those who observe them.

On the ocean protection cause screen there is also a tab that gives space to the 14 organizations related to the oceans, including one specifically that protects whales and dolphins.

The entire app has a simple design, organized and intuitive, in addition to having good performance.

Milkywire is a very complete application and explores the oceans cause very well with texts and videos about the work of those who are helping the marine biodiversity, however when we navigate to the organization’s screen, the importance of whales to climate change is not deeply addressed.

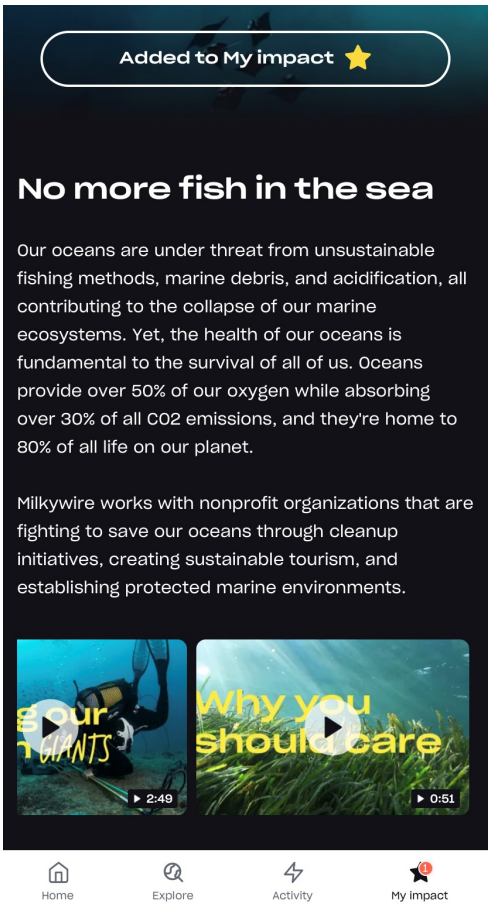

Figure 2.3: Milkywire "Save our ocean" Screen

2.2 Short visualizations

The most challenging part of the whole project was to develop a set of visualizations that, in just a few seconds, could create user empathy with a whale.

The research concludes that visual storytelling can make powerful contributions to helping people to overcome cognitive barriers, build emotional connections and, ultimately, change life choices to protect the environment. [14].

Nowadays we see that much of the time occupied by smartphone and tablet users is spent in applications, more specifically in social networks that are full of visualizations that absorb and make the users lose the perception of the time spent. Platforms like *Instagram*, *Facebook*, *YouTube*, *Twitter* and the most recent social network that significantly increased the download numbers, the technological phenomenon *TikTok*[1], has exactly the concept of short videos that are easy to watch and captivate the user and, if used well, can lead to assimilating interesting knowledge.

[1] Data from https://www.insiderintelligence.com/charts/tiktok-users-worldwide-forecast/

In this section, we will analyze some of the most viral videos on these platforms related to our thesis subject and try to understand why they achieve so many people and compare them to our 3D visualizations.

2.2.1 Whale avoiding vessels

The first video that we examined, presented in 2.4, was a work of Luis Bedriñana-Romano, a researcher and PhD at the University of Concepción in Chile, this 15 seconds scientific visualization that represents blue whale's movements trying to feed while avoiding vessels in an area with a high level of boat traffic in the Gulf of Ancud near Chile.

Figure 2.4: Frame of the whale avoiding vessels visualization

This video count more than 640.000 views and more than 7.400 likes on a *Twitter* post [2] and most

[2] https://twitter.com/ballenaschile/status/1356703048270249985

of the comments are related to the feeling created by the blue point and the empathy that it transmits, hereupon we concluded that the view achieves the goal of raising awareness what made of it a strong inspiration for our visualizations.

We consider this project so absorbing, differentiated, and well done that initially, we used the idea of simulating the real path of a whale that migrates between the island of Madeira and the Canary Islands but in the process of building the application we changed our minds.

Anyway, although the visualization shows the whale hazards to reach the people's feelings our target subject is a little different because we want to relate with the advantages of the whale to fight against climate change.

2.2.2 Whales in the fight against climate change

A video with four phrases about the importance of the cetaceans to help the environment. Succinct and interesting, it focused on whale carbon dioxide absorption capacity and their influence on phytoplankton growth. 16 seconds can enlighten who see about this unknown subject for many people.

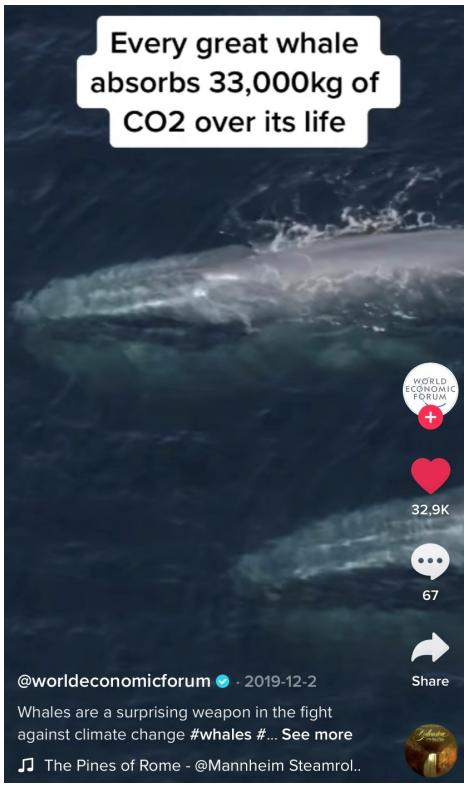

Figure 2.5: Frame of the *TikTok* video with information about the whales influence in the fight against climate change

This *TikTok* visualization [3] has more than 265.000 views and exceeds 32.000 likes. These numbers

[3] https://vm.tiktok.com/ZMLvP8vnf/?k=1

can explain the potential of *TikTok* and short videos in the spread of the message because even a visualization that apparently has not so much time invested could reach a huge number of persons.

The way that the images are presented can´t be compared with the ones in our project because they used real footage and we made animated visualizations however we can relate to the texts by being small although we have some more phrases.

3

User Research

Contents

Users' researches are very important as a source of information, through which we have access to statistics about the preferences of people when looking for informative platforms that after being analyzed, allowed us to make consistent decisions and consequently led to a better user experience.

The search for the need and how to build a solution is part of the user-centered design approach [15] since the application must fit what the user needs and based on that we could idealize the features of the our prototype.

With this in mind, before developing the application, a questionnaire was carried out to identify some key points in which 14 questions were asked through Google Forms [1] to 89 people, and all the respondents answered the same questions.

3.1 Survey

The intention of doing the survey was to create a more concrete idea of the hypothetical user of our project, on the one hand understanding the relationship with technological devices and on the other hand what they think about climate change and whether they were aware of the benefits of whales for the environment.

Surveys helped us to identify a target user population, pain points and opportunities that the solution could fulfill [16]. We have conducted the one presented in Appendix A.

We started with a question to understand the age of the respondents:

- Which is your age group?

The answers to the survey were given by people of all age groups, most of which were between 18 and 25 years old (33.3%) because initially we considered young people as our target audience since it is the age group of adults who will suffer most from climate change, however the more people know about the problem the better.

Then, four questions were shown to understand the relationship with technology:

- Do you like apps or websites more?
- How much time, on average, do you spend in front of your computer and mobile phone outside of work?
- What kind of content do you consume?
- Would you spend some of your time on your computer or mobile phone for the benefit of the environment?

[1] For more information https://www.google.com/forms/about/

This phase helped us to define what kind of platform we would develop since more than 55% of people chose apps over websites and it was an important initial step to continue to develop the idea of what we were going to build.

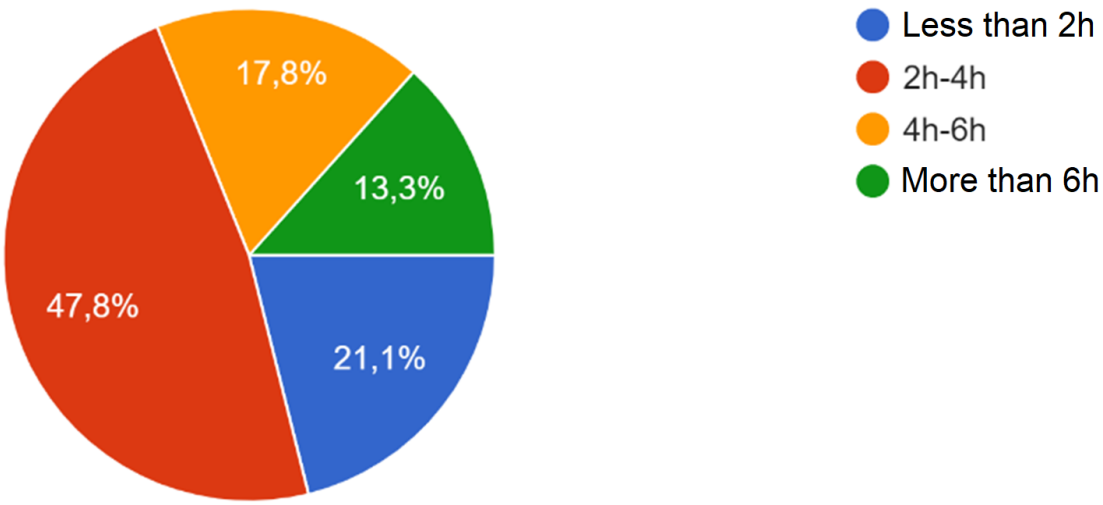

Figure 3.1: How much time, on average, do you spend in front of your computer and mobile phone outside of work?

The second question, presented in 3.2, serves as a call for attention to make the respondents think about the time they spend on the internet to reach the last question of this phase and understand if their are available to using a few minutes for something really important to the world and that fills them in some way, what often doesn't happen when after spending hours in front of a device.

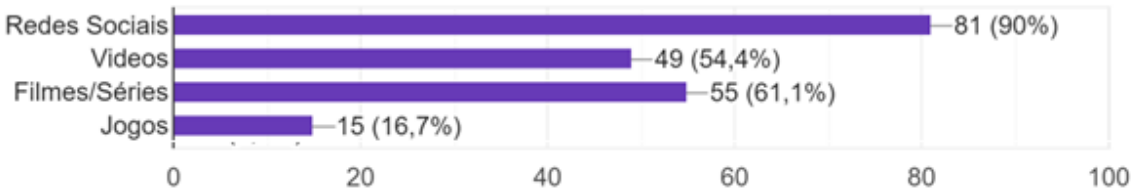

Figure 3.2: How much time, on average, do you spend in front of your computer and mobile phone outside of work?

More than 47% answered that they spend between two and four hours on the internet outside of work and approximately 54% use this time to watch videos (data extracted from the fourth question of the questionnaire), which helped us to bet on visualization as a way of transmitting the information.

In the last question of this set of the questionnaire 94.4% of respondents assumed that would spend some time on a computer or mobile phone for the benefit of the environment which led us to conclude

that there could be a demand for a knowledge transmission application about climate change.

The last 8 points focused on the topic of climate change:

- Does global warming worry you? If yes, what do you do to fight it?
- Have you ever watched a documentary about the subject? If yes, describe it in 3 or 4 adjectives
- Have you ever used an app or website that aims to help the environment or help raise awareness about the topic? If yes, which one? Describes the application or website in 3 or 4 adjectives
- Do you believe that global warming has a solution? If yes, list solutions that you believe can solve it
- Were you aware that whales could help remove CO_2 from the atmosphere?

Of the 89 respondents, only one said that global warming does not concern him and among the various responses to actions to combat global warming, many are indirectly related to the protection of the oceans.

Regarding documentaries, more than 76% of the respondents revealed that they had already watched at least one related to climate change which many describe as scary or synonymous, despite this approach in the case of our project we will opt for a positive framing, raising awareness through explanations of how whales can help the environment and not show how the planet is destroyed because this perspective can lead the viewer to lose hope and assume that there will be nothing else to do.

When asked about the use of technological platforms related to the topic of environment, around 3 in 4 people revealed that they had never used any, which would be expected given the low supply and dissemination in the mobile application markets and make us believe that there is a gap in the offer for a solution as ours.

Finally, more than 76% of respondents believe that global warming has a solution, but only 17 out of 89 were aware that whales help to reduce carbon dioxide from the atmosphere and when asked about possible solutions no one pointed to oceans as one thus making us bring interesting new knowledge to those who use our app.

4

Proposed Solution: Application

Contents

Taking into account all of the studies made until now about related works and users' opinions, the main goal when we started to build the functional prototype was to be sure that we get the most possible attention of the users to transmit all the information we want and aware them, if possible make the users share this so important information.

The initial part of the solution was to choose how we wanted to present the users the information about the whales, for this we believed that 3D videos, simple and dynamic graphs and succinct text information could hold the attention of the user. The next phase was to find out the technologies that fit better with the requirements described in the last paragraph.

After the technologies with the help of Marta Ferreira, the designer of the project, we selected the layout of the application screens and lastly I developed all the functional prototype content according to all the functionalities idealized before. In this section we will explain deeply the process.

4.1 Requirements

Before starting with technical issues, we needed to clarify how we wanted to reach the users and described the features in a very complete way don't have much chance of changes.

There were some doubts about the platform, firstly we did not know if it would be a mobile application or a website, however we already knew that we wanted that the platform would have 3D videos integrated to make the information more appealing but the content of the videos was not yet figured out.

Finally was a requirement that elucidate us, we wanted something to be exposed in a museum, school or a public space and to be one time used not a platform to use regularly.

With this clear we decided to develop an application with some explanatory 3D videos in it. After some design changes we assumed that the application should be made up of five screens:

- **Cover** with title, a button to navigate to the next screen and the possibility of changing the language
- **Menu** with three options about the phases of whale influence in carbon absorption and an explanatory text
- Three screens about whale influence in carbon absorption: With a video, dynamic graphs and explanatory texts

4.2 Technologies

The architecture of our application is only built with a presentation layer [17]. We made the flow very simple and intuitive and just concerned with the interaction between the user and the system.

To do a set of 3D visualizations we used a powerful technology called Houdini [1] and based on an answer of the user research presented in Section 3 how the respondents prefer mobile apps over websites we chose React Native [2].

4.2.1 Houdini

Houdini is a 3D animation software application that works in a procedural way and is used to produce modeling, rigging, animation, Visual Effects (VFX), look development, lighting and allows us to render in film.

In this framework, every action is stored in a node. These nodes are then "wired" into networks that define a "recipe" that can be tweaked to refine the outcome and then repeated to create similar yet unique results. The ability for nodes to be saved and to pass information, in the form of attributes, down the chain is what gives Houdini its procedural nature.

We opted for Houdini because it is a very known framework in the animation and VFX industry, does not require plugins and a free version of the application is available, furthermore and as important as the enumerated before it has powerful animation tools, creating sophisticated particles (necessary for the ocean replication) and dynamic simulations, procedural workflow and a great built-in render called Mantra. The only disadvantage that we found in our searches to choose the technologies before starting the project was that has a steep learning curve.

My experience with Houdini was good, I learned to work with Houdini for this project and as it is a complex framework initially learning and adaption was difficult for me. There are not many people that use it compared with other technological tools so there are not much information online however with the help of documentation and YouTube tutorials I could start understanding well and after months of learning with experience can say that had an easy fluid work with this framework.

One of the biggest challenges was to learn to move the camera and zoom the images to take advantage of the best angles.

I used Houdini Apprentice, a limited version of the software that is free of charge for non-commercial use but covered all needs.

The main disadvantage that I had to point out is the render time that is too much, I do not know how is with the other 3D applications but for example, a project video that has less than 50 seconds took more than 48 hours to render.

Overall I liked working with Houdini and consider that was a very enriching experience that made me more versatile and resilient.

[1] For more information https://www.sidefx.com/products/houdini/
[2] For more information https://reactnative.dev/

4.2.2 React Native

React Native is a User Interface (US) JavaScript framework, cross-platform for writing code that can render native mobile applications for iOS and Android, through a bridge responsible for performing a bidirectional and asynchronous communication between JavaScript code and native code.

It is based on React, a JavaScript library for building the US, characterized by encapsulated components that manage their own state. After each component is created we can share and join them to make complex UIs. React also primitives render to native platform UI, meaning the app uses the same native platform APIs other apps do.

Another advantage of this framework is fast refresh, which allows seeing render changes as soon as the code was saved.

One of the main advantages of using React Native, is the fact that I already worked with it professionally so we could achieve the solution sooner and we could try all types of designs and ideas. Furthermore we can use very well-designed and popular libraries, one of them is i18next [3] that we used in the solution, the library facilitates us to make a more dynamic translation.

In short was a good choice because the application had a great performance and we could do everything that we idealized, furthermore React Native is one of the most used frameworks for mobile development in the market so it is more easier someone continues the project, after providing the this project's code.

4.3 Application Features and Design Process

The core design of the application was made by Marta Ferreira after recurring brainstorms between all people involved in the project. The main goal was to reach users' awareness through a simple, interactive, attractive and differentiated product with an intuitive flow.

Using the Research through Design (RtD) method [18] the focus will be on empirical analysis to observe and measure performance, in other words, data from users will be acquired to be analyzed and guide the iterations of the prototype's developments.

The objective of using this type of design method is to have an investigation designed to make an application that can have an impact on users to the point of making a social change, helping communication and engagement of an environmental issue.

To begin the solution phase a low-fidelity prototype, presented in figure 4.1, was created to sketch the application. The idea presented in this prototype was to give to the user an overview of the problem of carbon dioxide and present the whales as a solution complemented this part with some topics about the subject, in addition to this we expected to create three whales personas.

[3] For more information https://www.i18next.com/

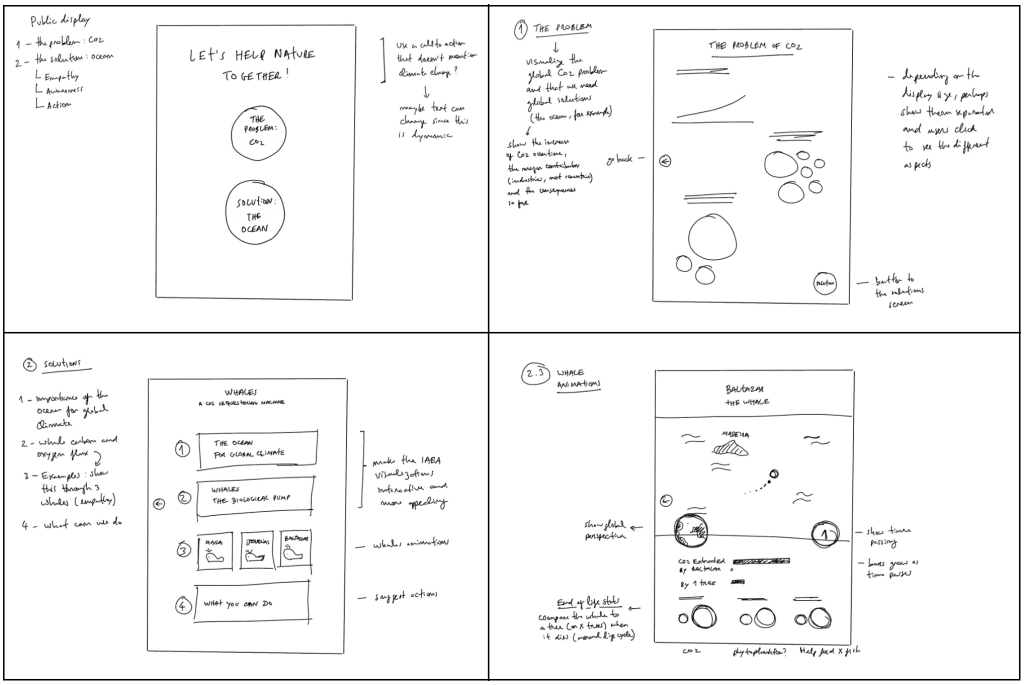

Figure 4.1: Low-fidelity prototype draw by Marta Ferreira

After the low-fidelity prototype have been validated, Minimum Viable Product (MVP) (in the context of a small project) was created by Marta Ferreira and posted in Adobe XD, then I implemented the first example of the functional prototype visible in 4.2.

The next step was to add some color to the screens but when we tested the application we felt that the subject should be explained in another way focusing on the way the whales are related to CO_2.

With this in mind we decided to firstly create a cover with just one button, a menu designated to our persona, the whale Dory, with three buttons, associated with the three phases of carbon absorption, that allow the user to navigate to a screen that has some data linked to each phase. The final prototype will be detailed in a further section.

4.4 Technical Implementation

This section will provide an overview of the development process and a general explanation of how the implementation was made.

4.4.1 Visualization Initial Idea

The implementation of the visualization started with a Comma-separated Values (CSV) file with geographic data of a pilot whale that moved between Madeira Island and the Canary Islands archipelago,

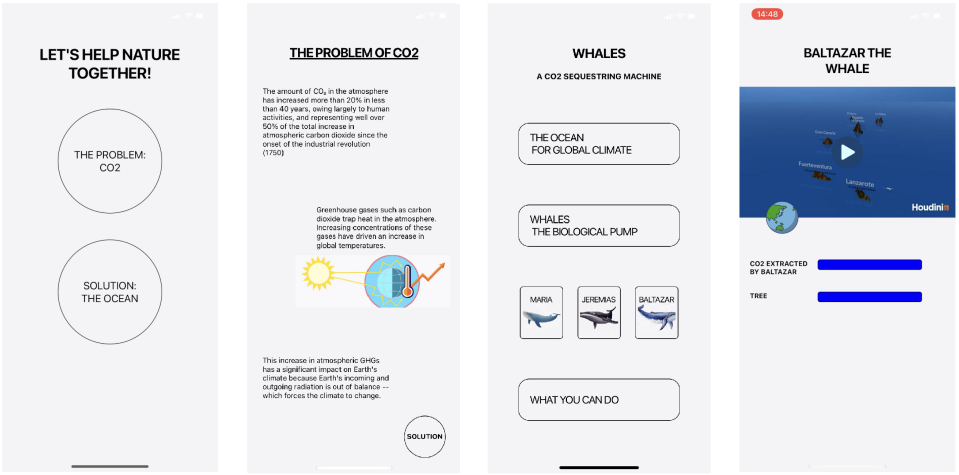

Figure 4.2: First functional prototype

collected by *Argos* [4]. The data was provided by Marc Fernandéz, a postdoctoral researcher that helped us along with the project development, and it turned out a very interesting development to follow whales and animate their real paths.

The first step we took with the data was to introduce it in *OpenStreetMap* [5] and the result is presented in 4.3.

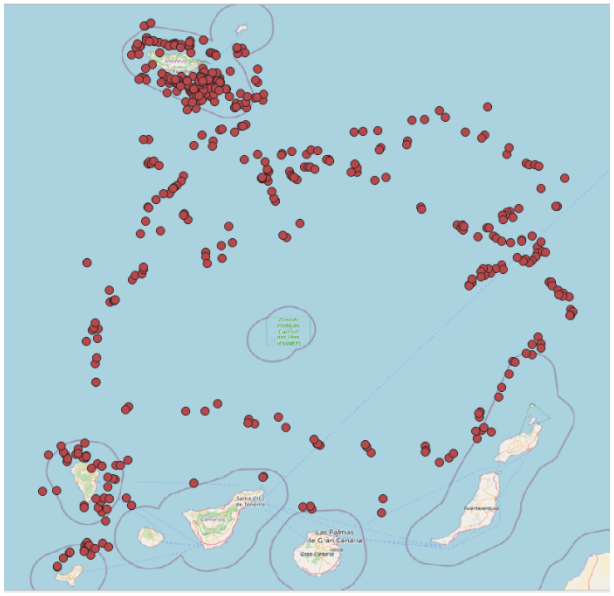

Figure 4.3: Pilot whale geographic data between 28th September 2018 and 11th January 2019

To import the geographic points to Houdini three dimensional plan we had to create a python script visible in Appendix B and introduce it in a ”Python node”. As Houdini take so much time to render we

[4] Global satellite-based location and data collection system. For more information https://www.argos-system.org/
[5] For more information https://www.openstreetmap.org/

only worked with data from 24th November 2018 instead of using all data sets (28th September 2018 and 11th January 2019), so the result was only the path around the Canary islands. All this process is shown in 4.4.

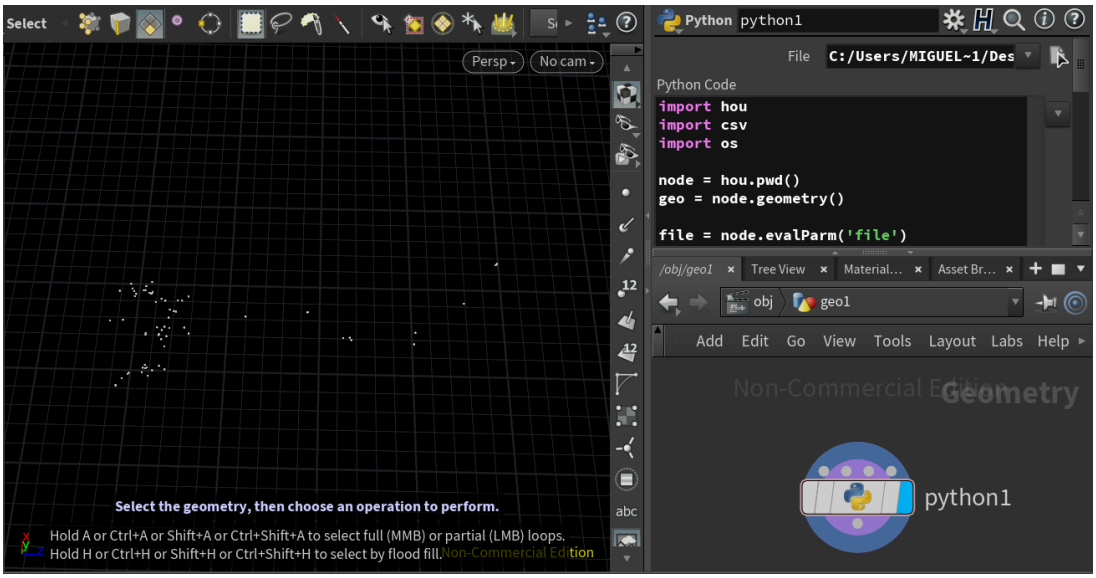

Figure 4.4: Houdini screen shot with result of geographic data import

After that, and to create a path, the points were joined and a whale object (.obj) was imported from the internet, a “Follow the Path” function was assigned to follow the drawn path and later the path was made invisible.

The next step was to import the islands, at this stage we used a “Mapbox node” which makes it possible to extract an area of the globe and give some height to the field.

We added an ocean node (set of many small particles) and the whale moved the particles away while swimming through the path.

To finish we placed a blue grid behind the scenery to make the sky and started the render. The final solution’s frame of this process can be visible in 4.5.

4.4.2 Visualizations Final Solution

After we changed our plans we decided to make an application about the relation of a whale with carbon dioxide instead of describing the climate change problem and solution, new visualizations were created.

The first one represents the migration of a whale from Alaska to Mexico, in this case we gave height to an image of North America, draw a line to simulate the migration and some other lines to simulate vessels paths and made each object follow their respective path. Then we added a grid to the sky and other to the ocean. To finish some words were added to explain where was the breeding and feeding territory, these words also have a path to fit in a way that they do not cover the whale or the ships.

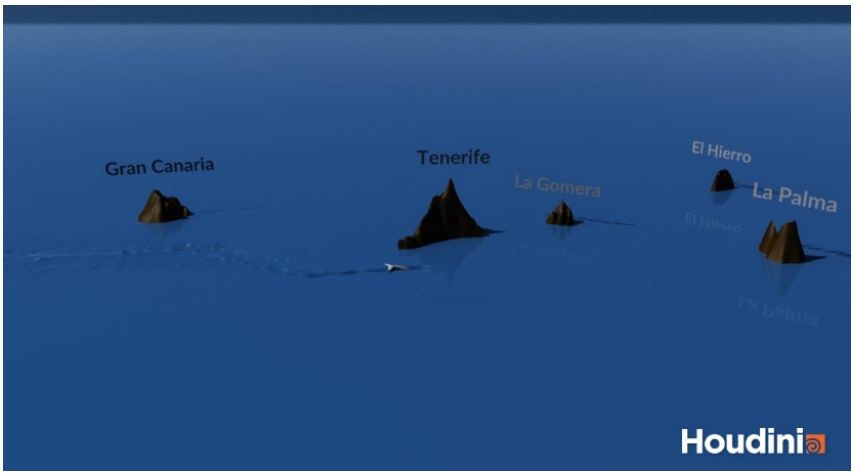

Figure 4.5: Visualization frame of the whale around Canary islands

In the second video we added a grid to the sky and ocean, created a path, placed a green cloud simulating phytoplankton and when the whale achieved the top of the ocean leave some brown fog simulating feces and the green cloud size increases.

In the last video we used the same sky and ocean as the second video, drew a path and made the whale object disappear when reaching the bottom while a carcass appears.

One other important implementation was the place of the camera which was changed through time according to the paths and zooms needed.

4.4.3 Application

As explained in subsection 4.2.2 the React framework is built with components, so we developed three different components inside a folder, one for cover, the other for menu and a third code for the screens with the animations, this last code information depends on the properties passed in the navigation triggered by the click on menu option buttons. Furthermore we created components that were shared by the screens, such as a header, title and progress bar.

Regarding styles, the sizes of the components depend on a ”Dimensions” interface, integrated into React Native. The width and height of the screen are stored in a constant [6] and can be divided and multiplied by any value to fit on all screens.

To version control and save the changes on the internet we used *GitHub*[7].

[6] e.g. const width = Dimensions.get(”window”).width
[7] The source code can be found in https://github.com/miguelpcoelho/MoreWhalesLessCarbon

4.5 Functional Prototype

In this section we will present a functional prototype with a fully-working set of features. In the following subsections all functionalities, components, screens, implementations, and technical facets of our application will be described in detail.

4.5.1 Cover

Opening our application, the first screen that appears is a cover, presented in 4.6.

Figure 4.6: Cover screen

Is a very simple screen where the user can change the platform language between Portuguese and English. This is possible by a framework called *i18next* that manages JavaScript Object Notation (JSON) files with the translations and detects the user language after the click in the flags.

In addition to language options, the screen has a round button that leads the user to the menu of the application.

4.5.2 Menu

After the cover, the user navigates to a screen where is presented our persona, the whale Dory and below that three options with moments that are related to the carbon absorption. This is the menu screen and is shown in Figure 4.7.

Dependent on the button chosen by the user, properties (object argument with data) will be passed to the next screen through the navigation route. That way the next three screens are all the same but with some different components.

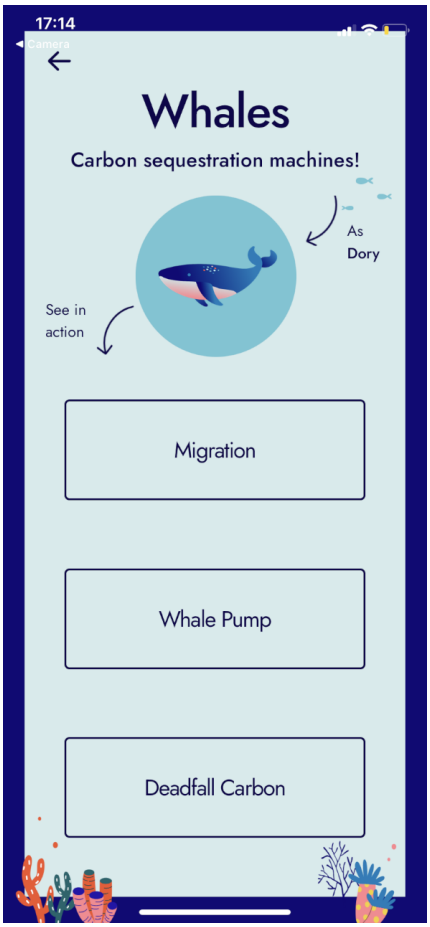

Figure 4.7: Menu screen

4.5.3 Migration

The screen shown in 4.8 is about the migration of a humpback whale. The visualization was based on a World Wide Fund (WWF) article [19] that represents a whale that is moving from the cold waters of Alaska which is a foraging area in around six months later arrive to the warm water of Mexico where it breeds.

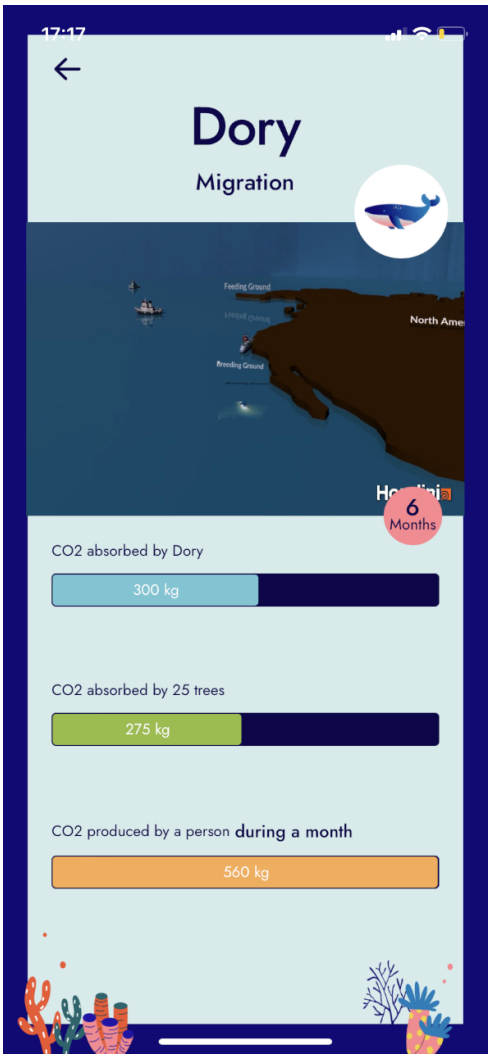

Figure 4.8: Migration screen

The two top horizontal graphics move according to the time of visualization and are related to six months.

The data from the whale was extracted in an article from the scientific magazine *PLoS One* [20] where it stated that each great whale sequesters 33 tons of CO_2 on average in their life, approximately 30,000 kilograms and as a humpback whale lived on average between 40 and 100 years we assumed [21] 50 years of a lifetime so we reach the 300 kilograms value in six months.

According to *European Environment Agency* [22] trees take up about 22 kilograms of carbon dioxide from the atmosphere.

Finally, for the last graph we used the information from the statistical office of the European Union, *Eurostat* [8] which stated that the total carbon footprint of EU-27 was equal to 6.8 tonnes of CO_2 per

[8] https://ec.europa.eu/eurostat/

person in 2019.

4.5.4 Pump

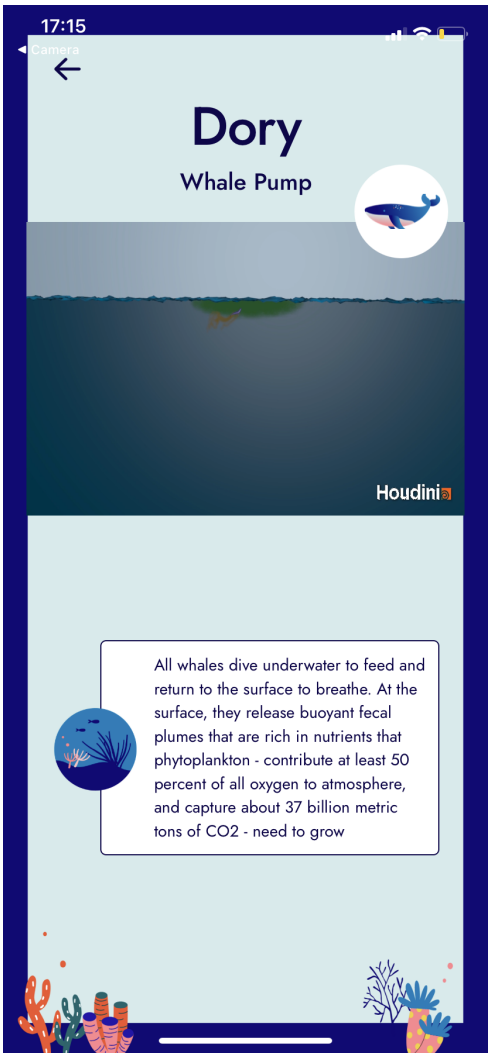

Figure 4.9: Pump screen

The pump screen presented in 4.9 was inspired by an article published in *PLoS One* Magazine [23].

Consisting of visualization explained in 4.4.2 and a brief explanatory text, this screen was made to detail the exact moment when the whale returns to the surface to breathe and simultaneously.

4.5.5 Deadfall

The deadfall screen represents the last phase of the relation between the whale and carbon dioxide. As shown in 4.10, the visualization together with text gives some details about what happens when the

whale, with the carbon inside, dies and goes into the ocean's deep [24].

The graph grows along with the video and the data are justified in subsection 4.5.3.

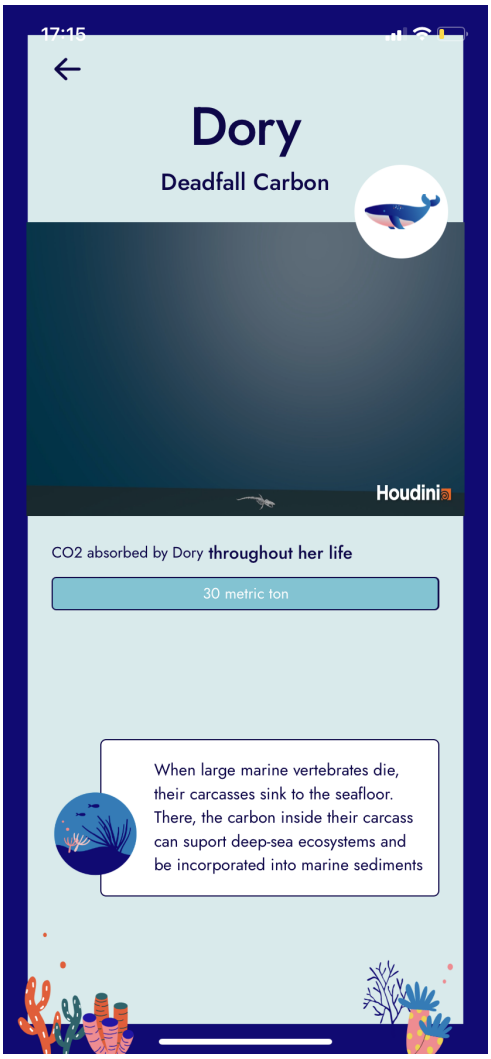

Figure 4.10: Deadfall screen

5

Evaluation

Contents

After developing an application according to requirements defined in 4.1, a group of users was subjected to an evaluation to assure that the solution met users' needs, achieved our goals and to understand what we can improve.

The first step was to ask the participants to respond to two forms, one for consenting data use and the other for demographic data and about the knowledge of the subject addressed in this project.

When they finished fulfilling the two initial forms, had an opportunity to explore the app, then they complete an easy task and finally answered a form about users' experience and application topics.

The last two points we will address in this section are not only a detailed analysis of the usability test results but also conclusions made from the data extracted in this experience.

5.1 Methodology

In this section we will explain all the processes that led us to the results of the usability tests.

We used summative assessment to identify achieved goals and usability deficiencies existing in our human-computer interaction final solution [25].

Was created a protocol guide to help us during the tests keeping all sessions as cohesive and similar as possible, this protocol is presented in C.

We presented the same three forms and the task, which we will describe in the following subsections, to all respondents and the evaluations were divided between qualitative and quantitative measures.

It should also be noted that the tests were carried out in spaces where only the researcher and the user were present.

5.1.1 Introduction, Consent Form and Initial Survey

As soon as the user met the researcher, was given a brief introduction to explain in general how would be the usability test and to show appreciation for the user's help.

After the introduction, a *Google Forms* link was sent to the user with the consent form where is explained that the answers will be anonymous, private and only for academic purpose and if he signs accepts to perform the test. The form is shown in Appendix D

Following the user has accepted and signed the consent form the link to the initial survey was sent with the goal of having a general knowledge about the demographic data and the knowledge the user had about the whales' relation with carbon dioxide. Appendix E presents this survey.

5.1.2 User First Interaction and Task

After fulfilling the two initial forms the user had the opportunity to explore all the functionalities of the application with a maximum time of five minutes. While had the first interaction could ask any question.

In terms of interaction between the user and the application our platform is simple and very intuitive, however we did not want to leave the performance of a task aside because that's the way the respondent pays more attention to the application itself and gives better feedback.

Taking into account the last paragraph we decided to ask the participant to navigate from the cover screen until the deadfall screen and let the video ends.

Following the task we were ready to get some qualitative data from a Retrospective Think Aloud (RTA) once we asked the respondents to describe the steps of the task and after that the researcher showed the video recorded with the actions taken in the task to recall, express their line of thought and express what they felt. During this stage, the researcher added some important commentaries to a notebook.

5.1.3 Final Debrief

After exploring the application, concluding the task and verbally exposing a qualitative view of the project, was sent a link with the last form to the participants to fill out.

The form included a first section where the respondent assesses the usability regarding the experience with the application. Despite one ”yes or no” question, all the other had an answer range that starts at 1 and goes until 5.

Finally we presented a test with three simple questions about the project to know if the visualizations and the texts were effective in transmitting information and consequently achieving the goal of raising awareness among the users about the whales' positive influence on the climate change problem.

The final survey is shown in Appendix F.

5.2 Results

In this section we present and analyze the results extracted from the usability tests. It begins by showing the respondents' characterization, then presenting an analysis of the quantitative evaluation, followed by a study of the answers in the knowledge test about the subject of the project and finally we expose some conclusions regarding the user opinions.

5.2.1 Users' Characterization

Regarding the initial survey about demographic data, 27 people participated in our usability study, of which 21 of them were between 20 and 29 years old and the remaining 6 were from 30 to 65.

In terms of occupation, 10 respondents were students, 3 of them worked as well, 19 were employed and one was retired.

About the knowledge of the participants on the topic in question in the project, 51.9% knew about the role of whales in the balance of the marine ecosystem and only 18.5% knew about the role of whales in carbon absorption.

5.2.2 Quantitative Analysis

Starting by analyzing opinions about one of the main features of the solution, the visualizations, only one person answered *No* to the question *Do you think that the format of the visualizations – character and map/timeline – helped you to contextualize the information?* what makes us agree that the visualizations made the difference and were approved by the users in general.

Following the other quantitative evaluation questions, for the first one we chose an answer range that started in *Very Boring* (1) and went until *Very Interesting* (5), for the next one the range was from *Very Confusing* (1) to *Very Intuitive* (5), finally the last four answers went from *Strongly Disagree* (1) until *Strongly Agree* (5). Figure 5.1 shows the results.

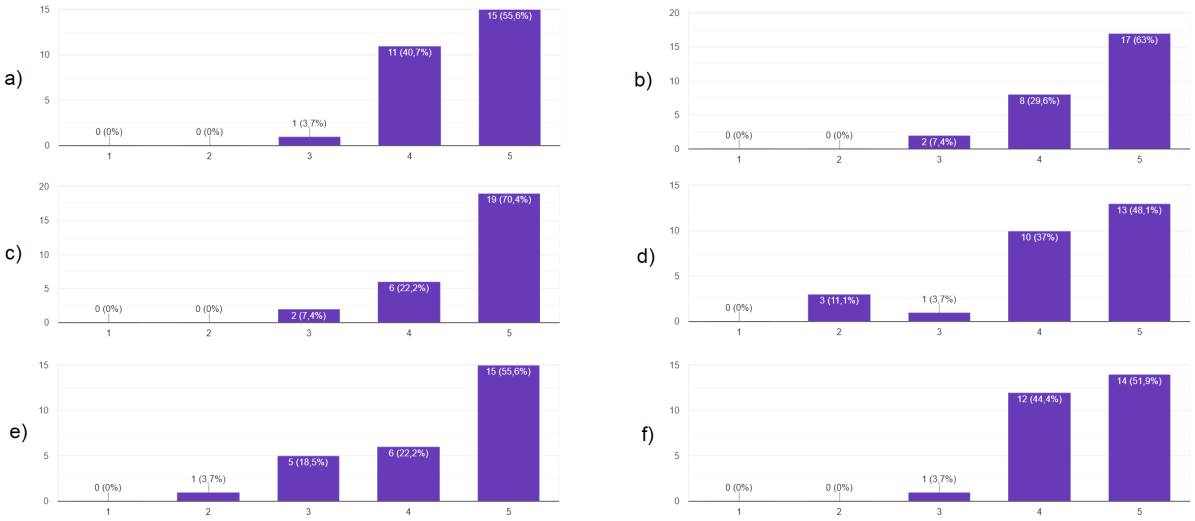

Figure 5.1: Post usability survey result: a) How do you rate the experience?; b) How do you consider the App?; c) Has the experience made you aware of the problem?; d) Has the App aroused your curiosity about the influence of the oceans and whales in the fight against climate change?; e) Did you empathize with Dory?; f) Would you talk about the topic with friends or family with the aim of raising awareness?

Most parts of respondents rate the experience as interesting (11 of 27) and very interesting (15 of 27) and only 2 of 27 consider that the app has a medium intuitive flow, with these results we can assume that our project has a good level in terms of user experience.

About the creation of a persona, whale Dory and the videos shown with the whale as a protagonist we asked if the user empathized with Dory to which 15 replied that they strongly agreed, 6 that agreed,

5 that somewhat agreed and 1 that disagreed.

In terms of the subject itself, 19 of 27 participants answered that strongly agree that the app could raise awareness about the problem of the whales. 3 respondents of 27 disagreed when questioned about the capacity of the app to arouse curiosity about the influence of the oceans and whales in the fight against climate change, however 10 agreed and 13 strongly agreed. Of the 27 participants, 26 agreed or strongly agreed that would talk about the topic with friends or family to raise awareness.

In general, the results show that the goal of raising awareness about an unknown however important theme was achieved with success.

5.2.3 Knowledge Test Analysis

To understand how good is our application in terms of transmitting the shown information and if the user is going to keep it in mind we chose to evaluate through a quick and simple test.

The first question was related to the graphics of the migration screen, presented in 4.5.3, where we asked between a tree and a whale who absorb more carbon and in this case only two participants were wrong.

Following, the next question was about the visualization of the pump screen, shown in 4.5.4, and we asked if the whales are a key player in the growth of Phytoplankton, 26 of 27 respondents got it right.

In the last question of the test, we decided to be a little more ambitious and find out who paid attention to the pump screen text asking what is the approximate percentage of Earth's O_2 produced by Phytoplankton, 55.6% of the respondents pick the right answer of the three possible choices.

With these results we concluded that the dynamic visual information like graphics and visualizations are more easily captured than text information.

5.2.4 Qualitative Analysis

After the conclusion of the task we conducted an RTA with each participant while we eared and wrote down what they considered the positive points and issues. The analysis of these comments will help us to get an overall perception of the user experience.

One of the main suggestions noted by 8 of the 27 respondents is related to the little amount of information. Some claimed that the texts could be more complete, others that there could be an introductory text in the menu screen and also suggested the integration of links that redirect to pages related to the topic.

Another issue pointed out was the fact that the screen has visualizations, text and graphics that appear simultaneously and take the focus off the video, which can make the users not follow what the video has to show. Of the 27 participants, 4 proposed adding sounds or simulating bubbles scrolling the

screen to make the experience more immersive.

This exercise also allowed us to find out some usability issues related to the videos that are difficult to stop and if we change the timeline of the videos the graphics still have the same behavior.

As positive points, 10 of the 27 participants highlighted the intuitiveness and simplicity of the general application, justified by saying that they understand everything that was being explained.

9 respondents referred that the videos have a good way to hold the attention making the application more interactive together with the dynamism transmitted by the graphics.

In short, most users supported the idea of the project being used in a museum or other public space and would be suitable for a younger audience.

5.3 Discussion

Every year the concentration of carbon dioxide in the atmosphere grows and with almost every decade that passes the growth rate of these values is increasing. We all know that this gas has immense harmful effects on our atmosphere consequently affecting living beings.

Hence there are more and more initiatives that aim to remove CO_2 through the most varied forms, such as innovative projects and the protection of natural extractors. It is common knowledge that trees store carbon removed from the atmosphere through photosynthesis, what few people know is that whales also play a very important role and each one is equivalent to thousands of trees.

This project aims aware the population about the benefits of a living whale has to the climate change in the world through an application equipped with a set of visualizations and gives to the users some concrete data about the subject.

We defined our requirements and developed a solution simple in terms of functionalities and design but with a complex implementation that holds the attention to transmit clear information that remains present in the minds of users.

From the analysis of the usability tests we conclude that our application was well accepted by the users in terms of experience, dynamism and subject however we can improve some aspects. Thus we believe that we achieve our goals, developing a solution that can easily transmit the information we want in a way that makes people think and consequently learn a new subject to comment on with family and friends spreading the message.

6

Conclusion

Contents

This thesis was chosen with a moral purpose, although the theme of visualization and human-computer interaction is very interesting, the main goal is to feel that it would make a difference in awareness among the most number of people possible, managing to transmit the message of the whales as a solution to climate change to all the people who had an interaction with the application.

The theme of carbon dioxide in the atmosphere and the fact that the amount of this gas does not stop growing should be at least frightening for everyone but even more for generations that will suffer a lot from it. It is upsetting that those young people, some of them who in a few years are going to be who will have the greatest influence on the future of the planet, are not aware that the present must be changed so that in the future they can live in a healthy world and deliver it as they found to the generations that succeed them.

Is very special to have chosen the theme of the importance of whales for cleaning the atmosphere because the most part of people have no idea of their environmental value.

The goal of this document is present research on some works related to the theme, applications and short videos, as well as the technologies that were selected for development. In addition to this we analyze the studies conducted that led us to take most of our decisions and conclusions as far as the project is concerned.

Our value proposition consists of an one-time use platform that was developed to be succinct and interactive, focusing on the user's attention and the capability of him or her to retain all the information presented. The visualizations were fundamental pieces for the user not to get bored and made the user learn without realizing it.

In short, the expectation is that the application will reach as many people as possible whether in schools, museums or other public spaces such as metro and bus stations and in a small or large way it can improve the air we breathe.

6.1 Future Work

We have made efforts to deliver the best user experience possible, but we agree that many things could be better.

This project besides the raising awareness about the advantages of the whales could evolve into an application that shows solutions and the users could take measures to help the whales and even have the perception of what their good actions imply through something that gives them the estimated numbers in terms of carbon dioxide captured.

Regarding the usability tests we could not use a large screen in a public space and this is also a task for future work.

Taking in account the results from the usability tests some features deserve more time and dedicated

work:

- Add more information for those interested in understanding better how the carbon dioxide capture mechanism works or a link to specific sites, could even be added the possibility for users leaving an email to receive news and articles related to the topic.
- When the video is being played, try to make it full screen and without simultaneous information. Removing any kind of distractions from the main functionality
- Make the screens more immersive with ocean animations and add sounds
- Improve video control in terms of usability

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A

Survey to User Research

Appendix to present the survey conducted before the implementation of the solution as preliminary research.

Caracterização do utilizador

A pesquisa que se segue foi conduzida a respeito da tese de mestrado do aluno Miguel Pires Coelho, que frequenta o curso de Engenharia Informática no Instituto Superior Técnico.

Estima-se que o tempo de resposta seja menos de 5 minutos.

O objetivo da pesquisa é recolher dados importantes para o desenvolvimento de uma aplicação que visa consciencializar a população sobre um tema relacionado com as mudanças climáticas.

As respostas serão completamente anónimas, confidenciais e apenas utilizadas para fins académicos.

Se tiveres alguma questão não hesites em contactar miguel.pires.coelho@tecnico.ulisboa.pt.

Obrigado pela cooperação!

*Obrigatório

Qual a tua faixa etária? *

- ◯ 18-25
- ◯ 26-35
- ◯ 36-45
- ◯ 46-55
- ◯ Mais de 55

Gostas mais de apps ou sites? *

- ◯ App
- ◯ Website

Quanto tempo em média por dia passas em frente ao computador e telemóvel fora trabalho? *

- ◯ Menos de 2h
- ◯ 2h-4h
- ◯ 4h-6h
- ◯ Mais de 6h

Que tipo de conteúdo consomes? *

- ☐ Redes Sociais
- ☐ Videos
- ☐ Filmes/Séries
- ☐ Jogos
- ☐ Outra: _____

Gastarias algum tempo do que passas no computador ou telemóvel em benefício do ambiente? *

- ◯ Sim
- ◯ Não

Aquecimento global

Inicie sessão no Google para guardar o seu progresso. Saiba mais

*Obrigatório

Aquecimento global

O aquecimento global preocupa-te? *

- ◯ Sim
- ◯ Não

Se sim, o que fazes para o combater?

A sua resposta

Já assististe a algum documentário sobre o assunto? *

- ◯ Sim
- ◯ Não

Se sim, descreve-o em 3 ou 4 adjetivos

A sua resposta

Já utilizaste alguma app ou site que tem o objetivo de ajudar o ambiente ou ajude a consciencializar acerca do tema? *

- ◯ Sim
- ◯ Não

Se sim, qual? Descreve a aplicação ou site em 3 ou 4 adjetivos

A sua resposta

Acreditas que o aquecimento global tem solução? *

- ◯ Sim
- ◯ Não

Se sim, enumera soluções que acreditas que possam resolver o aquecimento global

A sua resposta

Tinhas noção que as baleias podiam ajudar na remoção de CO2 da atmosfera? *

- ◯ Sim
- ◯ Não

B

Python import data code

Appendix to present the python code created to import the geographic data in Houdini.

Listing B.1: Python code

```
import hou
import csv
import os

node = hou.pwd()
geo = node.geometry()

file = node.evalParm('file')

COLUMNS = 'Latitude, Longitude'.split(',')

def main():
    if not file: return
    if not os.path.isfile(file): return

    with open(file) as fp:
        reader = csv.reader(fp, delimiter = ';')
        header = next(reader)
        header = {name: index for (index, name) in enumerate(header)}

        for row in reader:
            latitude = float(row[header['Latitude']])
            longitude = float(row[header['Longitude']])
            point = geo.createPoint()
            point.setPosition(hou.Vector3(longitude, 0, latitude))

main()
```

C

Guide Protocol to Usability Tests

Appendix to present the protocol that guide the researcher during the usability tests keep all cohesive.

Visualising the contribution of whales as a natural solution for climate change - Usability Test Guide Protocol

C.1 Material

Needed material before start the test:

- Mobile phone with the application initialized where would be possible to record the screen
- Mobile or computer to have access to the forms
- Notebook and pen to take notes
- Stopwatch to control the time the user explore the app

C.2 Introduction

Olá! O meu nome é Miguel Coelho, sou aluno do Instituto Superior Técnico e nesto momento encontro-me a terminar a minha tese de Mestrado em Engenharia Informática e de Computadores.

Neste momento preciso da tua ajuda para testar a usabilidade de uma aplicação que criei, com a ajuda do meu orientador e de uma designer. O tema da aplicação é a influência das baleias nas alterações climáticas.

A sessão será relativamente breve, com uma duração entre 15 a 20 minutos. Vou dando as indicações ao longo do teste, qualquer dúvida que tenhas não hesites em perguntar.

Obrigado pela tua participação!

C.3 Consent Form

After this introduction, present and ask the user to read carefully the consent form and sign. Doing it the user accepts participates voluntarily in the project and be aware about the data treatment.

This form can be seen in appendix D.

C.4 Initial Survey

Ask the user to answer a initial form to have an idea of demographic data and the knowledge that they have about the subject addressed in this project.

This form can be seen in appendix E.

C.5 User first interaction with the application

Let the user not only has the opportunity to explore the app in a maximum of 5 minutes but also ask all the questions about the functionalities.

C.6 Task - Go to deadefall screen and let the video ends

C.6.1 Introduction

Present the task to the user, tell that her/him won't have help and clarify any question that may have.

C.6.2 Performing the task

While the user is performing the task, time the process and pay attention to eventual errors.

C.6.3 RTA

Asked respondent to describe the steps of the task.

After the description show the video recorded with the actions taken, so that they can recall, express their line of thought and express what felt.

Take notes of all the answers.

C.7 Final debrief

Ask the user to fill the last form with a section that evaluates quantitatively the experience and other that will test the the knowledge transmitted by the application and the visualizations.

This form can be seen in appendix F.

D

Consent Form to Usability Tests

Appendix to present the consent form to read and sign if accepts the to perform the test and the respective conditions.

Formulário de consentimento

Foste convidado(a) para um estudo de usabilidade com o objetivo recolher feedback de modo a completar a minha tese

As respostas serão anónimas e apenas utilizadas para fins académicos

Os dados recolhidos serão privados

Inicie sessão no Google para guardar o seu progresso. Saiba mais

*Obrigatório

Li e compreendi as informações na descrição *

- ◯ Sim
- ◯ Não

Foi-me permitido fazer perguntas sobre a minha participação *

- ◯ Sim
- ◯ Não

Eu participo voluntariamente no projeto *

- ◯ Sim
- ◯ Não

Por favor preenche o teu nome *

A sua resposta

Por favor preenche a data em que estás a assinar o formulário *

Data

dd/mm/aaaa

E

Initial Survey to Usability Tests

Appendix to present the form used to collect demographic data about users that participated in usability tests.

Dados demográficos

Descrição do formulário

Por favor introduz o teu userID (fornecido pelo investigador) *

Texto de resposta curta

Por favor introduz a tua idade *

Texto de resposta curta

Qual é a tua ocupação *

Texto de resposta curta

Questionário sobre o conhecimento sobre o tema

Descrição (opcional)

Tinhas conhecimento sobre o papel das baleias no equilíbrio do ecossistema marinho? *

- ◯ Sim
- ◯ Não

Tinhas conhecimento sobre o papel das baleias na absorção de carbono? *

- ◯ Sim
- ◯ Não

F

Final Survey to Usability Tests

Appendix to present the form used to evaluate quantitatively the usability and to test if knowledge was transmitted.

Questionário sobre usabilidade

Inicie sessão no Google para guardar o seu progresso. Saiba mais

*Obrigatório

Como classificas a experiencia? *

	1	2	3	4	5	
Muito Aborrecida	○	○	○	○	○	Muito Interessante

Como consideras a App? *

	1	2	3	4	5	
Muito Confusa	○	○	○	○	○	Muito Intuitiva

A experiência conseguiu consciencializar-te? *

	1	2	3	4	5	
Discordo totalmente	○	○	○	○	○	Concordo totalmente

A App despertou a tua curiosidade pela influência dos oceanos e das baleias na luta contra as alterações climáticas? *

	1	2	3	4	5	
Discordo totalmente	○	○	○	○	○	Concordo totalmente

Achas que o formato das visualizações – personagem e mapa/timeline – te ajudaram na contextualização da informação? *

- ○ Sim
- ○ Não

Sentiste empatia pela Dory? *

	1	2	3	4	5	
Discordo totalmente	○	○	○	○	○	Concordo totalmente

Falarias sobre o tema com amigos ou familiares com o objetivo de os consciencializar? *

	1	2	3	4	5	
Discordo totalmente	○	○	○	○	○	Concordo totalmente

Questionário sobre o conhecimento transmitido pela App

Quem absorve mais CO2 *

- ○ 1 Baleia
- ○ 1 Árvore

As baleias são peças fundamentais no crescimento de Fitoplâncton? *

- ○ Sim
- ○ Não

Qual a percentagem aproximada de O2 da Terra produzido por Fitoplâncton? *

- ○ 10%
- ○ 30%
- ○ 50%