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Tapest[o]ry
Exploring the Interactive Capabilities of Tapestries as a Storytelling Tool

MASTER DISSERTATION

Laura Sofia Quintal Santos
INTERNATIONAL MASTER OF INTERACTIVE MEDIA DESIGN

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Resumo

Os nossos antepassados comunicavam histórias através de tapeçarias, utilizando-as para adornar espaços públicos e privados. Tradicionalmente, estas tapeçarias eram obras de arte estáticas penduradas em paredes sem interação com o público. No entanto, os têxteis oferecem um meio versátil, que pode ser criado a partir de vários materiais e cores e manipulado para produzir texturas únicas e sensíveis ao tato. A nossa visão é integrar as capacidades táteis da tecelagem com a tecnologia de sensores capacitivos para criar uma instalação artística interativa media imersiva que explore o impacto negativo da poluição sonora nos ecossistemas marinhos. Os animais marinhos, particularmente os cetáceos, dependem fortemente do som para a comunicação, navegação e caça, e a poluição sonora pode perturbar estas funções essenciais. Ao aproveitar o potencial narrativo das tapeçarias e o poder dos sensores capacitivos conectados a microcontroladores, desenvolvemos uma instalação artística única e imersiva que educa o público e quem tem o poder de tomar medidas sobre estas questões preocupantes. Os resultados qualitativos e quantitativos sugerem que o Tapest[o]ry é uma ferramenta de interface tangível e eficiente para contar histórias interativas e sensibilizar para a poluição sonora marinha.

Keywords: tapeçaria · instalações artísticas interativas · interfaces tangíveis · problemas na biodiversidade marinha · poluição sonora · e-têxteis

Abstract

Our ancestors communicated stories through tapestries, using them to adorn both public and private spaces. Traditionally, these tapestries were static artworks hanging on walls without interacting with the audience. Nevertheless, textiles offer a versatile medium, which can be crafted from various materials and colours and manipulated to produce unique, touch-responsive textures. Our vision is to integrate the tactile capabilities of weaving with capacitive sensor technology to create a media-immersed interactive art installation that explores the negative impact of noise pollution on marine life ecosystems. Marine animals, particularly cetaceans, heavily rely on sound for communication, navigation, and hunting, and noise pollution can disrupt these essential functions. By harnessing the storytelling potential of tapestries and the power of capacitive sensors connected to microcontrollers, we developed a unique and immersive art installation that educates the public and decision-makers about these pressing issues. Qualitative and quantitative results suggest that the Tapest[o]ry is an efficient tangible interface tool for interactive storytelling and awareness of marine noise pollution.

Keywords: tapestry · interactive art installations · tangible interfaces · marine biodiversity awareness · noise pollution · e-textiles

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List of Acronyms

BCTB Bare Conductive Touch Board

HCI Human-computer Interaction

IVBAM Instituto do Vinho do Bordado e do Artesanato da Madeira

TUI Tangible User Interface

UEQ User Experience Questionnaire

1 Introduction

A tapestry can be a contemplative art piece to entertain or to have a purpose, such as covering a wall, providing insulation from the cold, or decorating the interior of a home. Weaving tapestry is a craft technique frequently used by our ancestors around the world [3], that often portrays Bible passages and mythological or classical stories [4]. Usually, in exhibitions, people are not allowed to touch the art pieces because curators want to avoid seeing the exhibition as a playground or to prevent the artworks damaging by the visitors' touch. However, in contemporary art, some situations challenge this concept and frequently require the audience to interact with the art piece [5]. In this research, we revive tapestries' power to tell stories, educate, and entertain, but with an additional modern twist, using interactive technology.

Interactive technology progressively integrates physical objects without the traditional keyboard and mouse or display interaction style. The embodied interaction emerges from here, requiring different and new approaches to explain bodily action, human experiences, and physicality to interact with computational technology [6]. Haptic perception is intrinsically part of human natural interaction and communication with the world since humans use the touch sense to understand the surrounding environment [7].

Quoting Hiroshi Ishii, the head of Tangible Media Group at the MIT Media Laboratory, says: "We are tangible beings, not digital. Through human evolution, we have developed sophisticated skills for sensing and manipulating our physical environment through our hands, skins, bodies, and minds" [8]. However, nowadays, most of our surrounding information is stored in digital devices and displayed on flat screens, and we are limiting the practice of these natural human skills. From the perspective of Tangible User Interfaces (TUIs), giving a physical form to data will physically integrate them into people's surrounding environment [9]. TUI, connecting the digital and physical worlds, aim to take advantage of haptic interaction skills instead of the significantly different Graphical User Interface (GUI) approach, where the mouse or keyboard works as an intermediary to the display [6, 9]. TUIs enable the direct manipulation of digital information through our hands and perception through our peripheral senses by its physical embodiment [8].

Moreover, research on TUIs often explores the display stories in digital tangible interfaces. However, using TUIs as a medium language for storytelling is less common [10]. Previous research focuses on attracting new audiences through the potential of new creative and interactive approaches, highlighting the importance of engaging makers and interpreters with the creation of meaningful and personalized data narratives and through integrating technology with significant cultural crafts and their originality [10–12].

This project motivation emerges at the intersection of the tapestry potential as a TUI for interactive storytelling, the maker movement, and several contemporary projects and art pieces, such as Vanessa Barragão coral reefs [13], and Alexandra Kehayoglou landscapes [2], that highlight critical environmental messages. We also considered our personal background tapestries as inspiration and other initiatives and explorations from the maker community to reinvent tapestry, such as Judit Just wall-hanging weavings [14] and Felicia Murray textile textured projects [15]. Moreover, we found other explorations with textiles with embedded technology, such as Sophie Daniels with the hand-held interactive cube [16] and Hyojin Yoo with an interactive tapestry as a musical instrument [17]. We integrated technology seamlessly into the weaving tapestry threads, blurring the lines between the physical and the virtual, creating a unique, tangible storytelling interface.

This thesis has two primary research goals:

RG1: The creation of an interactive tapestry that tells a story to raise awareness towards marine noise pollution;

RG2: Assess the interactive tapestry impact on the audience in terms of audience engagement and usability with the final piece and the impact interacting with the piece will bring.

The following research questions guided this research effort:

RQ1: How can we design an interactive tapestry that serves as a TUI for a story?

RQ2: How can we integrate narrative elements in an interactive tapestry to raise awareness on biodiversity issues?

RQ3: Can conductive technology be effectively integrated with traditional tapestry techniques to enhance the synergy with multimedia content?

This thesis weaves in the art of Tapestry, Embedded Technology, Interactive Art Installations, Raising Awareness of Environmental Issues, and Storytelling (see Fig. 1) hoping that it might inspire readers and creators. Moreover, it contributes to the emerging field of TUIs for interactive storytelling with the interactive tapestry's artefact, documentation of its design process, and evaluation.

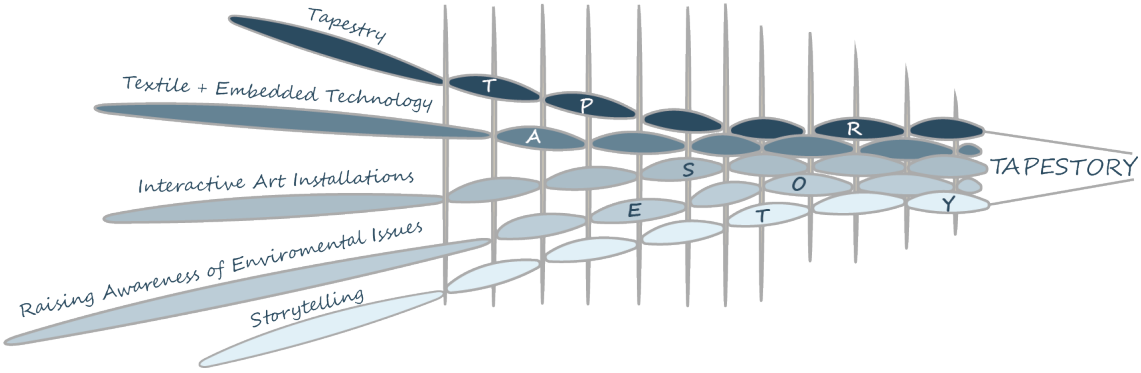

Fig. 1. Thesis Contribution

1.1 Overview of the document Structure

The next chapter analyses relevant related work that contributed to orienting this dissertation and discusses research opportunities.

Chapter 3 explains the initial design process, including several iterations of the conceptual design until our initial tests with wool and conductive materials.

Then, chapter 4 will focus on the final design process of Tapest[o]ry, where we explain the final decisions we made and the execution of the final prototype.

Chapter 5 will then explain our methodology to evaluate our interactive tapestry and show the results we collected from a pilot study.

In chapter 6, we discuss our results, answering the previous research goals and research questions and defining the project limitations and future work.

Finally, in chapter 7 we present our conclusions.

2 Literature Review

Throughout this research, we faced the constraint of finding theoretical and scientific bases to fundament the most practice-based area of this thesis, the tapestry weaving technique. Because of this, we searched not only for local information among the maker's community, such as artisanal and textile arts but also analysed their trends, focusing on relevant details, such as their concepts and their techniques and strategies to represent their concepts, as what they are doing to improve and innovate on their projects.

It was also important to understand concepts and what types of interactive technology are under research and used by the makers and researcher communities through the last few years.

We decided to divide this section by the following themes: 2.1. Tapestry; 2.1.1. Tapestry used for Anthropogenic Awareness; 2.1.2. Weaving Tapestry Technique, Materials and Stitches; 2.2. Embodied Interaction; 2.2.1. Embodied Interfaces for Interactive Storytelling; 2.2.2. Interactive Art Installations with capacitive technology; 2.3. Capacitive Technology for e-Textiles and Interactive Art Installations; 2.3.1. Arduino; 2.3.2. LilyPad Arduino; 2.3.3. Bare Conductive; 2.4. Research opportunities.

2.1 Tapestry

Our ancestors around the world developed several craft techniques for different purposes. The weaving tapestry was one of the most prominent and popular craft techniques. A thousand years ago, humans used natural elements like leaves and branches to produce their clothes, fashion tools and their houses [3].

In Europe, creating a wall-hanging weaving tapestry format was usual between the XIV and XVII centuries. Since a weaving tapestry was an expensive artefact, the elite was the most common population to have such decoration in their private and public spaces. During this period, weaving tapestries were also frequently used to tell stories. Most of them told bible, mythological and classical stories. Nevertheless, it was also usual to portray their life stories. During that time, it was easy to transport these art crafts to different places, giving the tapestries a less static difference from nowadays [4]. Through the years, tapestry forms changed and became associated with techniques other than weaving, like needlepoint, a more affordable craft technique [18].

The tapestry technique requires much work and time, mainly if it has big dimensions [4]. As said by Maddocks, weaving is a slow process which requires a lot of patience and focus. A weaver needs to be gentle while repeating many movements. Otherwise, it will distort the weaving result. She also emphasises that this slow weaving process brings well-being benefits that we should preserve since our daily lives are busy with many things to do, and we are constantly distracted by other stimuli. It is a craft activity that incentivises meditation and relaxation, essential benefits we are missing nowadays [3].

Weaving on a loom is considered by Maddocks a free craft. She also describes weaving as "painting with yarn" since it is possible to creatively create different pieces with several materials, textures, shapes, and colours after learning the basic rules. So, each person can freely create their style with their personality [3]. Maddocks gives the example of her learners, saying that, through the years, even children seem to use their intuition as an innate tool, creating craft pieces quickly [3]. However, technology and mechanical ability to create tapestries are replacing the manual ability of

weavers, even though some weavers continue to use the traditional techniques and explore different materials and new forms on their weavings [4].

Therefore, we searched for inspiration in the crafters' community, looking for what these textile crafters are creating and what features they use to explore new tendencies with the weaving technique.

Judit Just is a textile artist who creates designs for her weaving projects, creating 3D-like shapes with different textured threads and vibrant colours. She develops a concept primarily aesthetic, connecting with traditional craftsmanship techniques from her mother and weaving techniques she learned while studying fashion design, sculpture and textile art [14, 19].

Felicia Murray, a fibre artist who identifies her work as tactile, explores nature through the creation focused on colours and textures. She explores several textile techniques, such as tufting, felting and crochet, innovating with her versatile craft creations and exploring several mediums, from wall-hanging tapestries to tufted seats. [15].

These two examples explore the innovation of textile works due to their visual aspect and originality, exploring the potential of textiles, their shapes, materials and textures in a modern way.

2.1.1 Tapestry used for Anthropogenic Awareness

In addition to the innovative and explorative textile artistic expression, we also found some textile artists who use the tapestries' potential to tell stories, in this case, to use their work as a medium to tell and to share awareness messages for environmental issues, mainly caused or a consequence by man actions, with their audience [2, 20].

The artistic practices of Vanessa Barragão and Alexandra Kehayoglou frequently focus on environmental issues, reflecting their thoughts and perceptions of the Human negative influence on the world. Their art pieces usually aim to cause an impact and make the audience reflect on their conceptual message [2, 20].

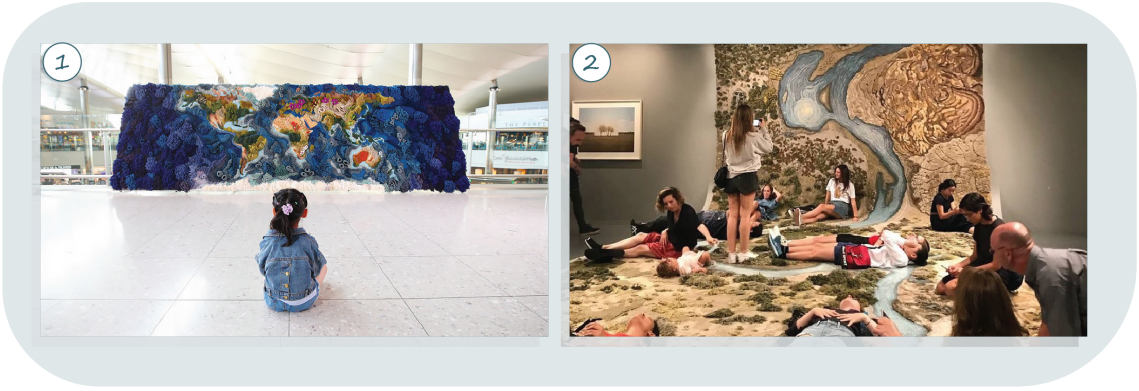

Fig. 2. Vanessa Barragão [1] and Alexandra Kehayoglou [2] artworks

Vanessa Barragão, a Portuguese textile artist, usually represents coral reefs with her textile practice. She creates giant textile pieces, using ancient techniques, such as tufting, latch-hook, and

locker-hook [20], to inform the public of threatening themes such as the impact of mass textile production on the marine environment and climate change. Moreover, through her tapestries, playing around with different techniques, textures and colours, she frequently explores the coral reefs concept, focusing on their blanching since coral reefs lose their colour when they are dying [13]. Since the textile artworks she is developing aim to spread the message she is working on, she exhibits her works in several locations around the world where many people walk through it, including an airport in Heathrow [1] and, more recently, a restaurant in Algarve [21]. A crucial objective of Barragão is that people contemplate her work and reflect on her conceptual message behind the technique. [1]. Image 1 from Fig. 2 displays this artwork at the airport in Heathrow, where several people walk through daily.

Alexandra Kehayoglou, an Argentine textile artist, usually represents landscapes with her textile artworks, creations with the hand-tufted technique, based on her ancient family tradition and the tufting machine technique, similar to hand-tufted technique, but mechanicalized. She uses her artwork to alert people to environmental issues like deforestation and devastation as consequences of human actions. These art pieces are frequently massive projects that impact the audience significantly, inviting them to reflect on her conceptual message. Some of her artworks also invite the audience to participate and utilise them while exhibited in a museum [2]. In image 2 from Fig. 2, we can see how extensive her work can be. It is capable of having several people seated or lying down at the same time while reflecting on the theme. Moreover, using a known traditional technique, her tapestry can display the concepts she is working on while creating landscapes with realism.

Barragão and Kehayoglou praise the additional feature of warning for environmental issues caused mainly by anthropogenic influences, hoping to transmit a conceptual message to the audience, which might influence their reflections and, in the future, their decisions.

2.1.2 Weaving Tapestry Technique, Materials and Stitches

Before moving forward, we must understand the terms of the weaving tapestry technique, including the types of material and stitches the technique uses. We should also remember that weaving is about using threads to create a unique piece of fabric.

Usually, the weaving technique uses a loom to hold all the warp threads [4]. The warp is the thread we use vertically up and down, held by the loom teeth or pegs, separated at equal intervals, to create a base structure for the weaving process, forming a backbone that holds the following threads. Moreover, the warp threads must contain a certain tension by being stretched to create the weft afterwards [3]. The weft is composed of every thread we interweave with the warp thread, which, lately, will allow us to have a unique piece. The weft threads usually run back and forth, creating blocks of colour. However, it is difficult to precise the expected quantities before the creation of a weaving tapestry [3, 4].

Traditionally, the weaving tapestry technique used wool as a primary material for the warp and weft due to its facility to dye or use it in its natural colour, presenting a natural strength and excellent flexibility to what weaving requires. Moreover, it also used other materials, such as silk and metal threads, in the weft to create details [4]. Modern weaving innovates using different materials, utilising their characteristics' potential, such as volume, texture, and colours. However, it is difficult to specify the expected quantities precisely before creating a weaving tapestry, even though we plan its design first. [3].

We can use several stitches with the abovementioned materials, focusing on modern weaving. Usually, we start a tapestry from the bottom to the top. We will now explain which stitch techniques exist and how to do them (we have not used all the existing stitches, so here, we only explain the stitches we used in our project).

Tabby or Plain Weave – This stitch is the most common and easiest to create. Assuming we are using a needle, we must hold it and pass it under the first warp thread, then over the second, and after, under the third, and over the fourth. We keep doing this until the end of a row, and then, we pull the rest of the thread. In the next row, we start on the opposite side and direction. This time, we pass over the first warp thread, then under the second, and after, over the third, and under the fourth, until the end of the row and pull the rest of the thread. It will make the opposite order of the first row. We must be careful when pulling the weft thread so it does not pull the outside warp thread, preventing the distortion of the final product. This stitch is flexible to create different area forms since we keep the basic logic in mind [3].

Rya Knots – Adding rya knots to weaving is a simple way to add texture. Usually, weavers use this stitch at the bottom of the tapestry, but we can also add it anywhere in the weaving. A rya knot can have the aspect of a fringe or a pompom, whether we leave it long or short, respectively. We need to cut several pieces of wool to do the rya knot. The size depends on the length we want to give to our fringes, and we must cut twice the size we want. However, if we want to create a short rya knot to have a pompom-like texture, we do not cut the final length it will have, but a bigger size that would allow us to execute the stitch, so we cut with the size we like afterwards. Moreover, the quantity of pieces of yarn depends on the volume we want to give to our texture. We do this stitch with our hands, without a needle. First, we hold the ends of the piece or pieces of wool, finding the middle of its length while folding them. Then, we put the centre of these pieces of wool above two warp threads. Each side of the ends of the wool will have to pass under around each warp thread, respectively. Then, we must pull both ends together until we knot it to the warp. We repeat as many knots as we need. Finally, we can cut it to the desired length. A good practice while creating the rya knots is to create at least three rows of tabby weaving between rows of rya knots to hold the knots and the warp threads together [3].

Soumak and Double Soumak – This type of stitch also creates a different texture to a weaving. It is a diagonal stitch that, when used as a Double Soumak, creates a texture similar to a braid. To do a Double Soumak to a specific area, we must have at least four times the length of wool of the rows we want to fill in. With this length of wool, we hold it in the middle and use this centre to start the stitch. First, we pass the loop it creates in the middle under the first two warp threads where we are starting. Then, we draw the ends of the wool inside the loop, creating a knot around the first two warp threads. After this step, we separate both ends and pass above the following two warp threads, and we pull the wool ends passing under around the same warp thread. We repeat the process through the following rows we want to fill in [3].

Egyptian Knot – The Egyptian knot has a similar execution to the Soumak and Double Soumak techniques. To do an Egyptian knot to a specific area, we must have at least four times the length of wool of the rows we want to fill in. With this length of wool, we hold it in the middle and use this centre to start the stitch. First, we pass the loop it creates in the middle under the first two warp threads where we are starting. Then, we draw the ends of the wool inside the loop, creating a knot around the first two warp threads and leaving the ends under the warp. After this step, we pass the ends under the following two warp threads, and we pull the wool ends passing

above and around the same warp thread. We repeat the process through the following rows we want to fill in. The braid form will be at the back side of the weaving [22].

2.2 Embodied Interaction

Interactive technology integrates physical objects to interact with, excluding the keyboard and the mouse interaction, as a medium to interact with a display. This research topic, explored by human-computer interaction (HCI) researchers, studies human behaviour, experience and physicality while interacting with computational technology. To design an interactive piece, we must analyse the embodiment concept in tangible user interfaces (TUIs), where the user can interact with physical objects as an input and output at the same time [6, 9]. We can consider the embodiment as the interaction through tangible systems and systems based on gesture interaction. This type of interaction might include different body movements from several physical interactions, from the fingers, hands and arms to the head and face or even the whole body. The embodied interaction design requires designing the user experience and predicting the user behaviour while interacting. The physical gesture implies thinking since gesturing helps to find solutions, which is relevant to the learning ability of tangible interfaces [6].

Human beings have always used the sense of touch to explore the world. We use the sense of touch to understand the characteristics of several materials, a relevant step while interacting with physical objects. We get to know textures through our haptic perception, where we evaluate the type of texture we are feeling, whether it is rough, hard, soft, dry, wet, or others. This exploration also leads us to feel emotions. In other words, we define our emotions related to the touch perception we have from an object, and lately, we associate that emotion with that experience [7].

Bardalai et al. studied how several materials were related to emotions, and from there, we can take the example of two different textures: faux fur and sandpaper. The first one is soft and associated with a relaxed and pleasant texture. This texture might determine our feelings, being happy, relaxing, comfortable, enjoyable, warm, calming, nice, pleasurable, heavenly, and soothing. On the other hand, the second has a rough texture, easily associated with unpleasantness. This texture might bring discomfort, irritation, alertness, pain, annoyance, stress, tension, nervousness, creepiness, and upset emotions [7].

HCI also brings the affordance term to this field. Norman and Gibson introduced the term affordance to this research community. Maher says that Norman defined affordance as the aspect of design that offers enough clues on how to use it on its function, giving examples such as a button that affords to someone press, which makes it clear what it is supposed to do. These affordances influence how the user interacts with the interface more than a graphical interface [6].

2.2.1 Embodied Interfaces for Interactive Storytelling

Interactive storytelling plays with how the audience perceives the narrative. The narrative plot can be predetermined or not. When designing an interactive story, we must consider storytelling and interactivity. The audience must participate in shaping the story to have interactivity, meaning the user can change the destiny of the narrative by influencing its outcome. However, there must be a balance controlling the narrative between the user and the author. We give the audience the components to build the story, such as the characters, the props, the external events, and the story world so that the user can shape the story outcome. [23, 24]

Furthermore, the current research within tangible storytelling focuses on exploring some systems' properties that explore interactive gestures or advanced technological spaces. A small quantity presents the exploration of tangible storytelling using itself as a medium for storytelling. Tangible storytelling usually has objects with embedded digital capabilities as features [10, 25].

Harley et al. present a framework where they focus on understanding tangible narratives, analysing 21 developed projects on seven essential features that rely on the perspective of the narrative and the user experience. These seven standard features are: 1) the primary user, focused on for what audience they created the medium; 2) the media, considering what type of media they used, noticing that usually appears as feedback, being the result of an interaction, which displays a portion of the narrative; 3) the narrative function of the tangible objects, representing the tangible object as a metaphor of something or directly the tool which allows navigating through the narrative; 4) the diegetic tangibles, if the used objects are a representation of it, or if they physically exist in time and space; 5) the narrative creation, meaning if the user can feel like the author of the results or not; 6) the narrative choice, if it has implicit choices, where the user discovers what happens after the interactions, or if it has explicit choices, where the user knows in forehand what will happen after the interaction; 7) the narrative position, classified between external position or internal position, is external, where they remove the user from the narrative, and internal, where they insert the user and its interactions in the narrative, and between exploratory and ontological, being exploratory where the user explores the narrative to uncover or learn about the narrative, and the ontological, where the user can make decisions which might change the state of the narrative world [25].

While investigating the storytelling potential of craft techniques, we found several examples where the community uses traditional craft techniques to tell their stories. An example is the project that Guridi et al. [12] developed, where the traditional craft technique, the Arpilleras, and electronic technology were explored with children for them to tell stories. Arpilleras is a craft technique from Chile that surged in the 70s, built from embroidered fabric pieces to potato sacs. At first, women created these art crafts to earn money and then as a way of free speech while communicating stories from a controversial era in Chile. Since then, it has been a craft with a storytelling potential. However, through the years, it has been a craft that the Chilean community is losing interest in learning. This project allowed the craft technique to evolve among children's stories by joining electronic technology to display the sound of the narrative characters' dialogue and light.

Crafting Stories [26] is an interactive e-textile book based on an old interactive textile book made in the early 80s when the author was a child. It is an updated version of the old one, where the author adapted smart and electronic textiles and used several textile techniques and electrical components, creating a different approach and transforming the book's narrative experience into a tangible interactive story, with promising results among children.

Letters to José [27] is a tangible storytelling project where the authors developed a paper artefact to tell a story about the letters sent between two characters, José and Jesús. The user has the vital mission of interacting with the artefact to hear the story. The story displays Jesús's letters about his life and what was happening in Colombia with social changes during the late 40s. Three paper worlds allow the user to unfold the story physically through paper mechanisms and visual, performative, and auditory features. There are two microcontrollers controlling this experience. The first is a Bare Conductive Touch Board that detects touch and displays the narrative by

touching the visual elements made with carbon-based paint connected to the microcontroller. The second is a NodeMCU ESP8266 that controls a RFID (radio frequency identification) module that reads each artefact element with a tag. It also controls photocells, reed-switches, and thermistors, which allows audio clips of the narrative to play. This pictorial also contributes to research between the intersection of TUIs relevant narrative and interactive narrative theories.

2.2.2 Interactive Textiles

Researchers have explored electronic textiles (e-textiles) since the mid-1990s. Areas such as engineering, design, music, and art often create, develop and manipulate products with this type of technology. The interest behind this technology is highly focused on embedding light and audio on textiles [28].

Moreover, it is essential to distinguish e-textile technology from wearable technology. The wearable technology has no restricted materials or techniques and uses incorporated computational devices to be worn directly on the body. E-textiles focus on creating electrical circuitry, exploring different fabrication methods with conductive materials, such as conductive threads or textiles [28].

The Partnership Quilt, an interactive project that aims to change the lives of socio-economically disadvantaged people in the United Kingdom, such as the homeless, unemployed and suffering population. This project involved the creation of a quilt incorporating low-cost DIY capacitive touch sensors connected to a Bare Conductive Touch Board. These connections would allow it to detect the human touch. This project comprised several quilting techniques, such as English paper-piecing, applique, machine-quilting, and tie-quilting. For a year, problematic people worked on this quilt as an occupation, distraction, and a way of having socialising moments between its creators [29, 30].

Moreover, after finishing the quilt, they extracted parts of several reflections on the history of the quilt, the techniques they used to build it, and the experiences they had during the process of this project. They exhibited the final product, allowing the visitors to touch each rosette to display these audio records. We can emphasise that this example explores the crafting, technology, and storytelling feature, which offers engaging experiences that may impact the community positively [29, 30].

The creation of several toolkits to prototype is also an emergent research. Examples of this perspective are the Wearable Bits [31] and the Punch-Sketching [32]. The Wearable Bits is a co-design toolkit to help scaffold new wearable designs with embedded technology. They use fabric cards and swatches with embedded sensors to rapidly prototype new wearable e-textiles on the body [31]. The Punch-Sketching initiative explores the use of e-textiles and the potential to reuse crafting techniques and technology. They created a toolkit that uses the punch needle craft to prototype and encourage makers to create similar projects, where they explore the facility to iterate the design process physically. Moreover, they use technology such as LilyPad components and conductive materials such as Karl Grimm conductive thread [32].

Furthermore, we found Sophie Daniels's work, which explored a collection of interior designs for end-of-life settings. The design incorporates interactive elements, with embroidery textures, braille and sound. In this collection, she developed a hand-held tactile, interactive sound cube which aims to connect the patients' healing to nature's restorative benefits and, consequently, with memories of their lives. This cube uses the sensory abilities allied to electronic components and a

Bare Conductive Touch Board to display nature sounds [16]. With this invention, she filled a gap between the interior spaces and the wellness industry, raising accessibility to nature for everyone.

Artists and creators are also developing projects with embedded technology. The artwork of Hyojin Yoo, the Interactive Textile: Touch, can also be an example of what the maker community is developing. In this case, the artist explored the weaving tapestry technique with regular wool and conductive thread. The human touch and presence display harp sounds [17].

We also found some direct Bare Conductive Touch Board references, such as the Soft Cuddly Tentacle from Helen Leight, which uses electrical circuitry to develop an interactive piece. The BCTB has a stored sound on the SD card, and the electrical circuitry is made with conductive thread, creating a capacitive touch sensor. When the user strokes the tentacle length, it triggers a purring sound [33].

2.2.3 Interactive Art Installations with Capacitive Technology

Research on interactive art installations often compares them to traditional art pieces due to their physical composition. It is usual to have them in public spaces where the visitors can interact with them. However, something differentiates traditional art pieces from interactive art installations. The installation can change depending on the visitor's interaction or other surrounding factors. The interactivity factor is crucial to the artwork, as is sharing the artist's message with the public, sometimes including the visitors as a part of the installation while interacting with it [34].Another difference is that visitors are not allowed to touch the artwork in traditional art because it can damage it. In interactive art installations, it is usual to ask for, as a priority, the visitor's active participation in the artwork [5]. There are several types of interaction, from a simple static format to a more complex dynamic format. We can also analyse the interaction from three perspectives: the "interaction rules", the "triggering parameters", and the "content origin" [34]. The interaction rules define the level of interaction between static and dynamic, according to the type of interaction the user has, from simple actions to direct influence on the artwork by body gestures. The triggering parameters focus on the triggering factors that activate the interaction rules, defining if the user interaction is intentional, expecting the user to do some specific action or unintentional when it only requires its presence. And the content origin that defines the content the installation will present to the visitor. This content can be generated or predefined by the installation artist. Even though this content might be pre-defined by the author, the user might be able to manipulate it [34, 35].

We found examples of interactive art installations with embodied interaction and embedded technology. An example of this is the team Studio PSK challenged the capabilities of the Bare Conductive Touch Board and Electric Paint, creating an Interactive Polyphonic Playground Installation, combining music, design and textiles for a Design Festival, and also including a BeatBox performance. They used conductive thread, Electric Paint, and conductive tape as sensors. An essential part of the experience was making people play with the objects, so they invited visitors to touch the playground elements to trigger different sounds and change the soundscape [36].

Another example is Format 3, created by Foo/Skou. The project also uses the Bare Conductive Touch Board and Electric Paint, linked with other materials. It is a sound experience that uses an app and sculptures to touch. They utilise symbols to represent music through graphical notation. The project aims to consider technology's role in our relationship with the physical world [37].

2.3 Capacitive Technology for e-Textiles and Interactive Art Installations

There is diverse hardware that works with textiles. Arduino [38] and Arduino-related boards, like LilyPad Arduino [39] are easily adaptable to textiles [40]. Similar to LilyPad Arduino, Adafruit GEMMA M0 [41, 42] and Bare Conductive Touch Board [43] are easily adaptable to textiles and reprogrammable with Arduino IDE. Furthermore, other hardware like ChibiChip from Chibitronics [44], MakeyMakey [45], Microbit [46] and Tekniverse Bluebird [47] are available for similar electronics projects.

Arduino Integrated Development Environment (IDE) is a tool created to write code (using C or C++ programming language) and facilitate uploading to Arduino-compatible boards [48, 49].

2.3.1 Arduino

Arduino brings advanced technology products to anyone capable of interacting with the physical world. Arduino has a lot of developed hardware, including different boards, shields, carriers, kits, and electronic accessories. It offers tools to learn how to use its materials, including a starter kit where they suggest starting with Arduino UNO Rev3 to learn the basics of coding and electronics [38].

Arduino UNO Rev3 is USB-connectable, and it has several input and output ports to connect components, such as sensors and actuators [50]. Although Arduino suggests it as an easy tool to explore electronics and coding, they also created Arduino Nano, which has a specially made design for e-textiles [40].

2.3.2 LilyPad Arduino

LilyPad Arduino was launched in 2007 and is an example of embedded computation, a board designed for soft wearables that easily allow any user to sew it to textiles. It comprises a microcontroller, sensors, and actuators. It has small holes that allow the user to connect conductive thread easily. It is a kit that aims for kids and adults to do experiments with e-textiles in a simple and creative way [39].

Furthermore, LilyPad MP3 Player can trigger sound with the audio files from the micro-SD card when connected to the ground [51]. LilyPad, compared to Adafruit GEMMA M0 and Microbit, is considered the most sewable for textile projects [52].

2.3.3 Bare Conductive

Bare Conductive aims to make electronics and interactivity accessible to electronics novices and gives tools for electronics pros [43]. The Electric Paint, their first creation, is a highly conductive black water-based ink that can add capacitive sensing to any object [43]. The Bare Conductive Touch Board, their hardware, is a technology that allows reprogramming the board efficiently with Arduino IDE [53]. Its capacitive touch sensors are adaptable to different conductive materials, and it is possible to reprogram the touch sensors to proximity sensors [54].

It is a pre-programmed microcontroller with 12 electrodes that allow the connection with conductive materials as sensors. It also has a microSD card reader that allows storing MP3 files to trigger while touching or approximating the electrodes, a MIDI Synthesizer and a 3.5mm audio socket that permits reproducing instrument sounds or stored MP3 files [54].

2.4 Research opportunities

Weaving tapestry has a considerable history as a craft technique that, through the years, has explored its potential to tell stories. Modern weavers, such as Judit Just [14,19] and Felicia Murray [15], are exploring and innovating the potential of tapestries in terms of visual aspects, such as technique, materials, textures and colours, reviving the weaving technique. With our tapestry, we are interested in taking advantage of the potential of the visual aspects of the weaving stitches to create a visually appealing tapestry. However, they use the technique without adding a more complex message.

Therefore, Vanessa Barragão [1,20] and Alexandra Kehayoglou's [2] tapestry explorations innovate techniques, focusing on the visual aspect with its textures, materials and colours. Moreover, they also use the technique potential to express a more significant message and share it with the audience. They relate their messages to the result of anthropogenic actions, which cause pressing environmental issues, calling for attention from the audience who sees, reflects, and is aware of their conceptual message. We see this as an example of what is possible to create in terms of worrying concepts but with a different tapestry technique, weaving tapestry.

TUIs background generally involves digital interactive storytelling through displays. However, as TUIs are emerging, we saw several research approaches where exploring art crafts as a medium tool to display interactive storytelling is feasible. The Arpilleras [12] explore a traditional textile craft medium with embedded technology for storytelling among children. The Crafting Stories [26] explores an e-textile book for storytelling and playing with materials and textures for children. The Letters to José [10] explores a paper craft mechanism for storytelling that emphasises the user role within the experience. From the storytelling through a crafted artefact to thinking of the narrative details and the user role during the experience, we have not found any tangible interface for storytelling made of a weaving tapestry, allowing us to explore this unknown field. Since the user interacts with the hands, we must also consider that gestures help find solutions so we can use our tapestry with a narrative that aims to improve knowledge about a pressing issue [6].

In the HCI field, recent research also explored embedded technology with textiles, giving rise to the creation within the embodied interaction. The Wearable Bits [31] and the Punch-Sketching [32] present creative toolkit solutions for e-textiles, encouraging the maker community to prototype quickly within the e-textile domain. As these examples, we wanted to generate documentation encouraging and inspiring researchers and the maker community to innovate with a design process for tangible interfaces, reviving craft techniques.

Other explorations within e-textiles included The Partnership Quilt [29, 30], a crafted quilt created by social-economically disadvantaged people as occupation, which includes capacitive technology, the Sophie Daniels [16] healing cube interior design for connection to nature, the Hyojin Yoo [17] tapestry that displays harp notes with the user's touch and the Helen Leight Soft Cuddly Tentacle [33] with an embedded electrical circuitry. These projects emphasise the characteristics of touch as a medium for feeling emotions. Bardalai et al. [7] explore these features, and we can explore and take advantage of the weaving textures given by different materials and types of stitches. Moreover, even though the projects from Sophie Daniels [16], Hyojin Yoo [17] and Helen Leigth [33] integrate capacitive technology, they do not merge the storytelling potential, which is where our project emerges.

Furthermore, we found explorations related to interactive art installations. Trifonova et al. say that an art installation suffers changes with user interaction [34]. The Studio PSK [36] project invites the audience to intervene, letting them assume control of the space soundscape, touching conductive elements. Moreover, Format 3, with its touch-reactive sculptures, also invites the user to assume control of the interaction, where they can trigger sounds touching different conductive components present on sculptures and use an app with augmented reality through reading printed symbols on paper and textiles. These examples engage the audience through art with embedded technology and make them think of the audience's embodiment in a space where they can intervene and change its reality. Therefore, this is where we want to intervene, thinking of the user's role during the experience.

With the design process and evaluation of our interactive tapestry that weaves in a story to raise awareness for pressing anthropogenic issues, we aim to revive the tapestry's storytelling potential and contribute with a tangible narrative approach to the makers and research communities.

3 Conceptualisation and initial explorations of Tapest[o]ry Design

Due to the tapestry medium rich storytelling possibilities, our idea ever since from the beginning of this thesis was to use the tapestry as an interactive interface to tell a story that would leave the audience with an awareness message. Hence, we started our research for the story with a pressing theme that deserves attention: Biodiversity and its threats. When discussing biodiversity, we can consider all the living beings on earth and ocean/water, including diverse species and ecosystems. Each ecosystem element has a unique purpose while interacting with the others. However, biodiversity also brings nature-related changes and environmental pressure affected by anthropogenic actions [55].

In the initial stage of the project, we decided to explore two different avenues for the story theme, the Laurisilva Forest Biodiversity and Marine Biodiversity. This exploration allowed us to understand the most problematic threats of each theme, to develop some sketches to understand the different possibilities to design of our tapestry, and eventually allowing a more informed decision on which theme to develop in to the final concept. The following subsections explain this process of analysing the two different kinds of biodiversity, explaining concerns about these environmental issues, and for each topic, we share our initial concept designs. Towards the end, we focus on the rationale for the final theme to develop and the several iterations of the tapestry design after that. The final subsection of this chapter focused on the initial material explorations that we did to test the viability of our design concept.

3.1 Laurisilva Forest Biodiversity and its Threats

Islands like Madeira, Azores and Canary are known for having the presence of the Laurisilva Forest for a thousand years. In the case of Madeira Island it was certified as a world heritage by UNESCO for having the most well-preserved Laurisilva Forest in the world. The presence of the laurel tree is the most common characteristic of Laurisilva, from where came its name. The forest has many endemic species, such as trees, animals and other organisms. All these species contribute to maintaining the ecosystem life of Laurisilva [56–58].

However, Laurisilva's ecosystem is under constant pressure. The most concerning threats, qualified as high threats, are the presence of invasive non-native species and the risk of fire and fire suppression because of fire-prone species presence. The last ones might cause uncontrollable fires [59]. Most of these invasive species have a beautiful aspect and do not seem offensive, making people believe everything is fine with our nature.

For this first possible theme, we did three sketches. Fig. 3 and Fig. 4 display sketches of two possible tapestry versions for the invasive non-native/alien species theme. In both sketches, we decided to create two different phases of the forest. The first sketch, Fig. 3, represents both forest types in one piece, and the second, Fig. 4 , in two pieces, each representing two different forests. In both cases, the bad side of the forest, with appealing flowers, invades and consumes the good side of the forest, with local trees.

The concept presented in Fig. 5 aimed to raise awareness of the fire risk due to the fire-prone invasive plants. This design represents the fire consuming the forest, starting from the already burnt area to the close, healthy forest of Laurisilva. It displays four different phases of the forest state. The first top left corner represents the healthy Laurisilva Forest. The second phase displays the

Fig. 3. Invasive Non-Native/Alien Species first sketch

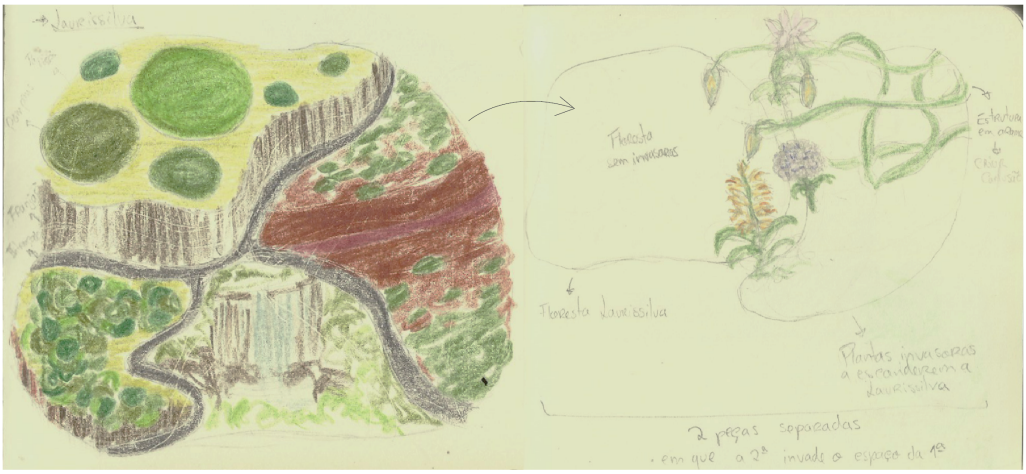

Fig. 4. Invasive Non-Native/Alien Species second sketch

presence of invasive species. The third phase represents the fire consuming the forest. Furthermore, finally, the fourth, in the bottom right corner, displays the already burnt area.

In all these concepts, our idea was that the user touches the tapestry elements to display some media, in this case, sound. To differentiate the bad and the good sides, we aimed to give different textures and forest-related audio to the different sides to cause the user different emotions and senses. For example, we can have smooth textures with healthy forest sounds to generate comfort and rough textures and disturbing sounds to cause discomfort.

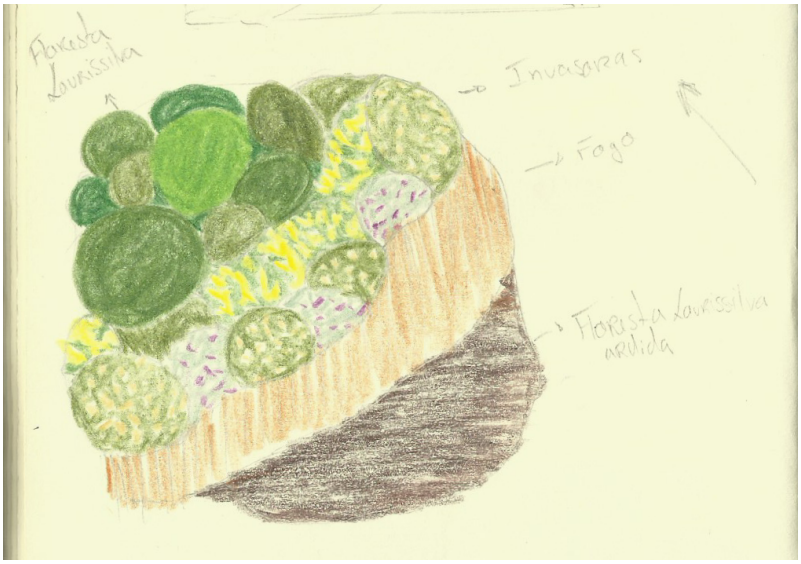

Fig. 5. Risk of Fire sketch

3.2 Marine Biodiversity and its Threats

Marine biodiversity is the composition of animals, plants and microorganisms that maintain the balance of the oceans. It is essential to keep the adaptability of marine species to maintain a healthy ocean. Comparable to Laurisilva Forest, the ocean and its ecosystems are also affected by threats. Among its threats, the most concerning ones are pollution, climate change, overfishing and bycatch, and other human-related impacts that change the everyday life of the species in the ocean [60]. Here, we found that pollution is one of the principal threats, and it can appear as chemicals and trash but also as noise. Noise pollution has increased over the last decades. Under the water, the sound is one of the most essential things for marine species. They use it as a medium to communicate, navigate, localise their companions and prey, escape from predators, and protect their territory. Sound pollution affects this kind of life activity of marine wildlife, and sometimes it even causes death [61]. Humans are responsible for noise pollution in the sea in several ways. Some noise causes are ship traffic, explosives, seismic airguns and military sonar [62]. Whales, in particular, are highly affected by anthropogenic sounds invading their territory. Whales are getting scared, injured, and having difficulties finding their way home, other mates, predators, and prey [63].[1] Furthermore, fishermen catch many non-permitted and permitted species that are not

[1]For a better understanding of marine noise pollution impact, watch the following video: https://www.youtube.com/watch?v=t0DHEldqfIc

in the expected quantities every year. This fact leads species to difficulty maintaining a healthy population and sometimes to the extinction of a species [60].

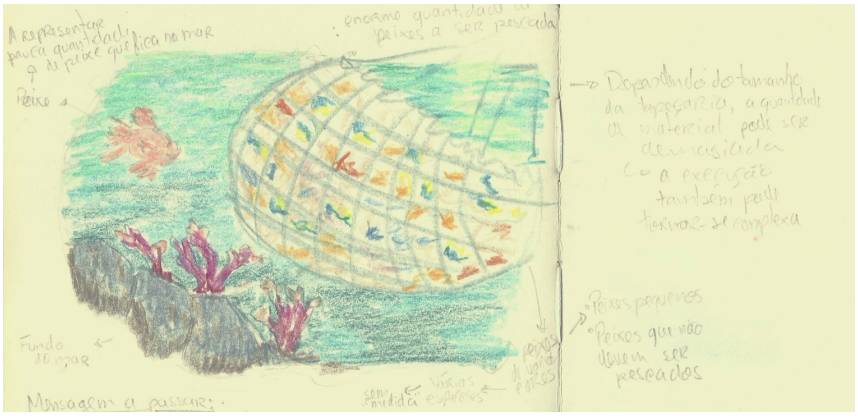

Fig. 6. Overfishing and Bycatch sketch

Thinking about these facts, we drafted a design for this theme. The sketch in Fig. 6 represents the overfishing and fishing of forbidden marine species. This drawing emphasises this concept while a fishing net removes amounts of fish from the sea. We can see that the net still leaves some fish in the ocean, but not enough to maintain a healthy population.

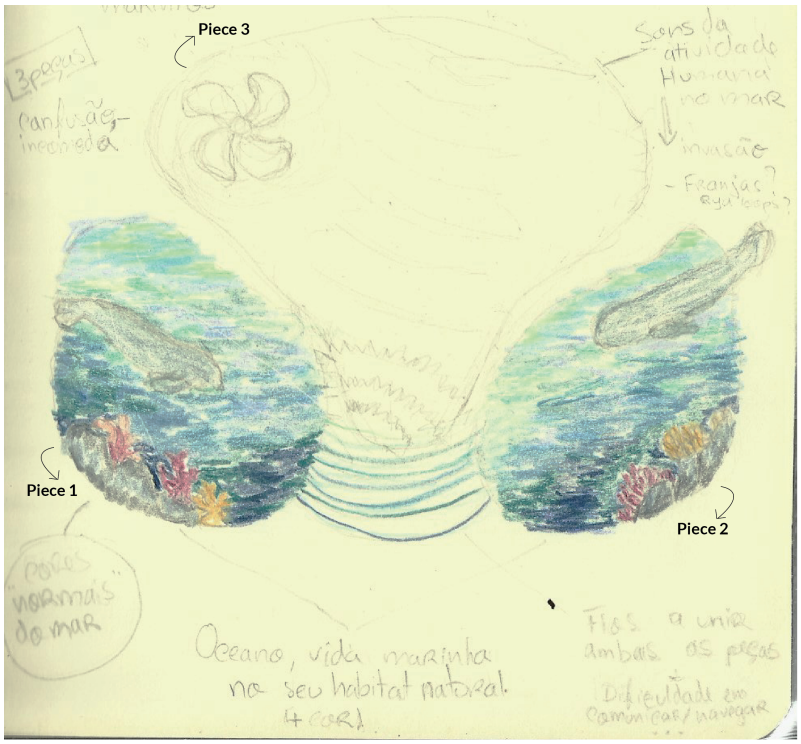

Fig. 7. Marine Noise Pollution sketch

This tapestry would work similarly to the previous ones by touching the elements to reproduce sound. However, the invasive element, the fishing net, would display a disturbing sound when the

user touches it. Its textures and sound will also follow the same logic as before. When the user touches the fishing net, he feels its rough texture and hears an agonising, causing discomfort.

The last sketch, Fig. 7, intends to emphasise the concept of marine noise pollution and educate the audience about the terrifying noise that marine life constantly faces. The two bottom pieces represent a regular ocean separated by its threats. It connects directly to anthropogenic sounds. In contrast, the third piece intends to represent the human-generated sounds invading marine ecosystems because ship traffic, seismic airguns, military sonar and explosives sounds are increasing and consequently affecting marine life [62].

This last design sketch uses the textures and the sound. However, it also explores the possibility of projecting images as feedback when the user touches the tapestry. We were thinking of a possible animation to explain the threat.

As a final decision theme, we chose this last one. It seemed a possible and viable project since we found much information to work with, even though it is a theme that needs attention.

As previously said, cetaceans are a highly affected species by anthropogenic sounds. Whales, for example, communicate by producing high-pitched sounds and hearing at significant distances. However, the sounds generated by men are higher and more disturbing, having a significant impact on their future health [62]. Noise pollution also affects other species, like the clownfish. Clownfishes use sound to find their home, the anemones in the coral reefs. When the noise invades the oceans, this mission is compromised when the clownfish cannot hear the sounds of the reefs [64]. After carefully analysing these designs and the gathered information, we decided that working with the theme of marine noise pollution would be the best choice for our chosen media. Firstly, it was possible to find relevant information about marine biodiversity, especially marine noise pollution. Secondly, we have not found projects with the same environmental issues as this last one. Finally, between all the possibilities, this theme is the most related to sound and probably easier to identify sounds.

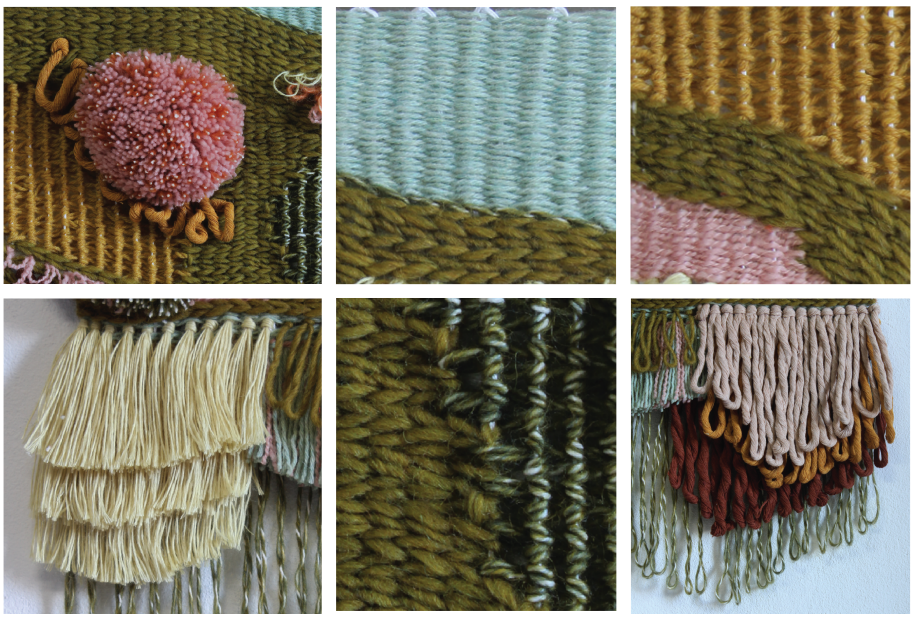

Fig. 8. Different Textile Techniques from a previous work

We considered previous artwork designs we did in another context for all the previous sketches, imagining a new version adapted to the themes we thought for this project. We assumed it would be possible to create textures similar to those shown in Fig. 8, where we used wool to create several types of stitches, such as rya knots, tabby, double soumak, Egyptian knots, and rya loops. These stitches enable playing around with volumes and textures and mixing different types of wool and cotton threads.

We envisioned our project based on this free, modern style of weaving, where we saw the potential to create smooth textures that call the audience's attention by presenting an appealing tapestry weaving with several textures for them to touch and affordances for them to understand what to do.

3.3 Tapest[o]ry Theme Conceptualisation and Message

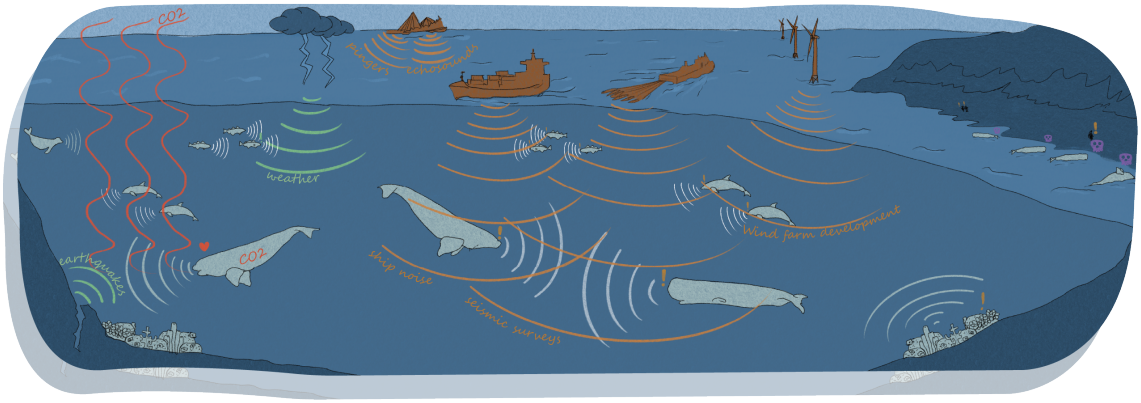

Fig. 9. How anthropogenic sound affects the marine ecosystems

Initially, our motivation behind this endeavour resulted from two central focuses. First, we focused on how tapestries' rich storytelling history and their visual storytelling capabilities can be a rich medium to raise awareness about critical issues. Furthermore, the second was how, through embodied interaction, we could transform a piece of art into a living, interactive experience where viewers become active participants in creating and exploring the artwork.

However, after our initial research, it became clear that we also wanted to leverage the touch and visual allure of a tapestry with the immersive and evocative nature of audio. As it was critical for us for these factors to interweave (and after much research and ideation), it became clear that the subject of our piece would focus on marine noise pollution and its effects on marine biodiversity.

Cetaceans, including whales, are highly affected by anthropogenic sounds [63]. Whales communicate using high-pitched sounds that can travel significant distances. However, the sounds generated by human activities are louder and more disruptive, impacting the marine ecosystem. Despite this, whales are crucial to the marine ecosystem and hold significant ecological and cultural importance [65]. They act as remarkable carbon sequesters, with their massive bodies storing carbon for extended periods. When whales die, they sink to the ocean floor, removing carbon from the atmosphere and mitigating climate change by reducing atmospheric carbon dioxide levels [63].

Through our interactive tapestry, we can amplify the voices of marine life suffering from marine noise pollution to highlight this critical issue, foster dialogue, and encourage positive action in a more sustainable marine environment.

3.4 Final Story and Conceptual Design Iterations

We previously decided to move on with the Marine Noise Pollution Theme. This section will explain the evolution of the design process from the initial sketch to the final one. The design of this interactive tapestry suffered several iterations during this process alongside our concept and narrative shifts. These involve the overall design with weaving techniques, textures, user interaction and our vision for the narrative's progression.

3.4.1 Design Iterations

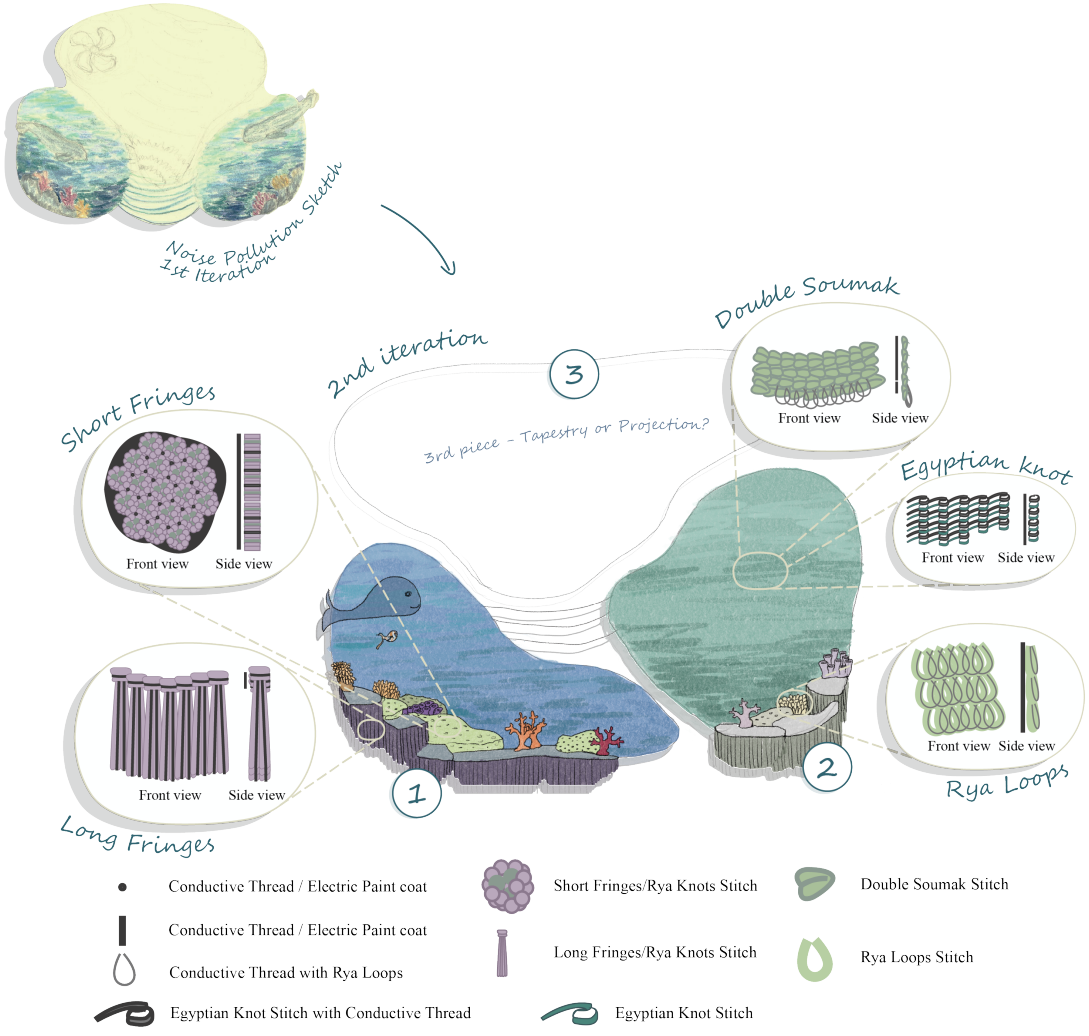

Fig. 10. 2nd Iteration Sketch: (1) First Piece;(2) Second Piece;(3) Third Piece

We did a first iteration of the initial idea, improving our design and ideas. In Fig. 10, we share our second iteration, where we started to think of adding the conductive materials and the

techniques we would use in the tapestry. We also improved our initial idea, mainly focusing on the tapestry's second piece. Instead of having a good ocean on both bottom tapestries, the second piece would result from human intervention, meaning it will damaged, represented with desaturated colours and rough textures. We also decided to have two characters in our narrative, so we sketched a whale and a clownfish on the good side of the ocean. We would maintain the third tapestry as noisy obstacles displayed through a projection or a tapestry.

The conductive materials we expected to use in this design (see Fig. 10) would be the conductive thread and some panels behind the tapestry painted with Electric Paint. These panels would be the same size as the sensor areas we wanted to create, and we would connect them to the Bare Conductive Touch Board. To ensure the sensor areas would work, we would use conductive threads mixed with the weaving stitches in those areas of interaction.

Then, while improving our narrative, we finally defined that the third piece would be a tapestry, and all the media we would use would be audio (see image 1 from Fig. 11). These decisions made a massive change in our process. We finally imagined the interactive piece as a total experience where the user follows a journey continuously from the left to the right side. We would have three pieces where the first and the last would represent the good side of the ocean, and the second would represent the anthropogenic influence. The characters would live a journey, where they start by giving the user an understanding of how they live daily. Then, they would go to the second piece, where they meet a significant threat: human activities in the ocean. Moreover, to finish their journey, they will go back to the good ocean, the third piece.

However, we soon understood that this improvement was not logical since the idea was that the characters eventually get back to the good ocean. So, when we think of getting back, we usually come back to the initial place and do not continue to another place. Therefore, the most significant change between the third and fourth iterations (see images 1 and 2 from Fig. 11) is the reduction of a tapestry piece, meaning that the characters would return to the first piece instead after their adventure.

Until now, we still had not defined how to represent human activities, and this was another significant change we made for the fifth iteration (see image 3 from Fig. 11). We thought a ship would be the most common and understandable figure to represent human activities in the ocean since it is also a worrying threat to marine life ecosystems. So, in this iteration, we added two blue ships to represent the obstacles the characters will face during their journey. Nevertheless, the colour of the ships did not have enough impact on the design. For that reason, we decided to use a more robust colour that disturbs the composition of the design, image 4 from Fig. 11.

We also decided to make a green area entering the blue area of the ocean in the fifth iteration (see image 3 from Fig. 11). This area means that the invasion from the polluted piece is coming to the healthy side of the ocean if humans do not take action at any moment, reducing their impact on the oceans. It will also introduce the polluted ocean to our characters.

Another small change was the visual sound waves we added to the left tapestry so that when the user places the whale, this sound wave will come from her.

With all the primary sketches done, we still had our characters to imagine. We wanted to create two friendly characters, a young whale (see image 5 from Fig.11), and a young clownfish (see image 6 from Fig. 11). Our goal here was to simplify their visual, making it still recognisable. Their sizes

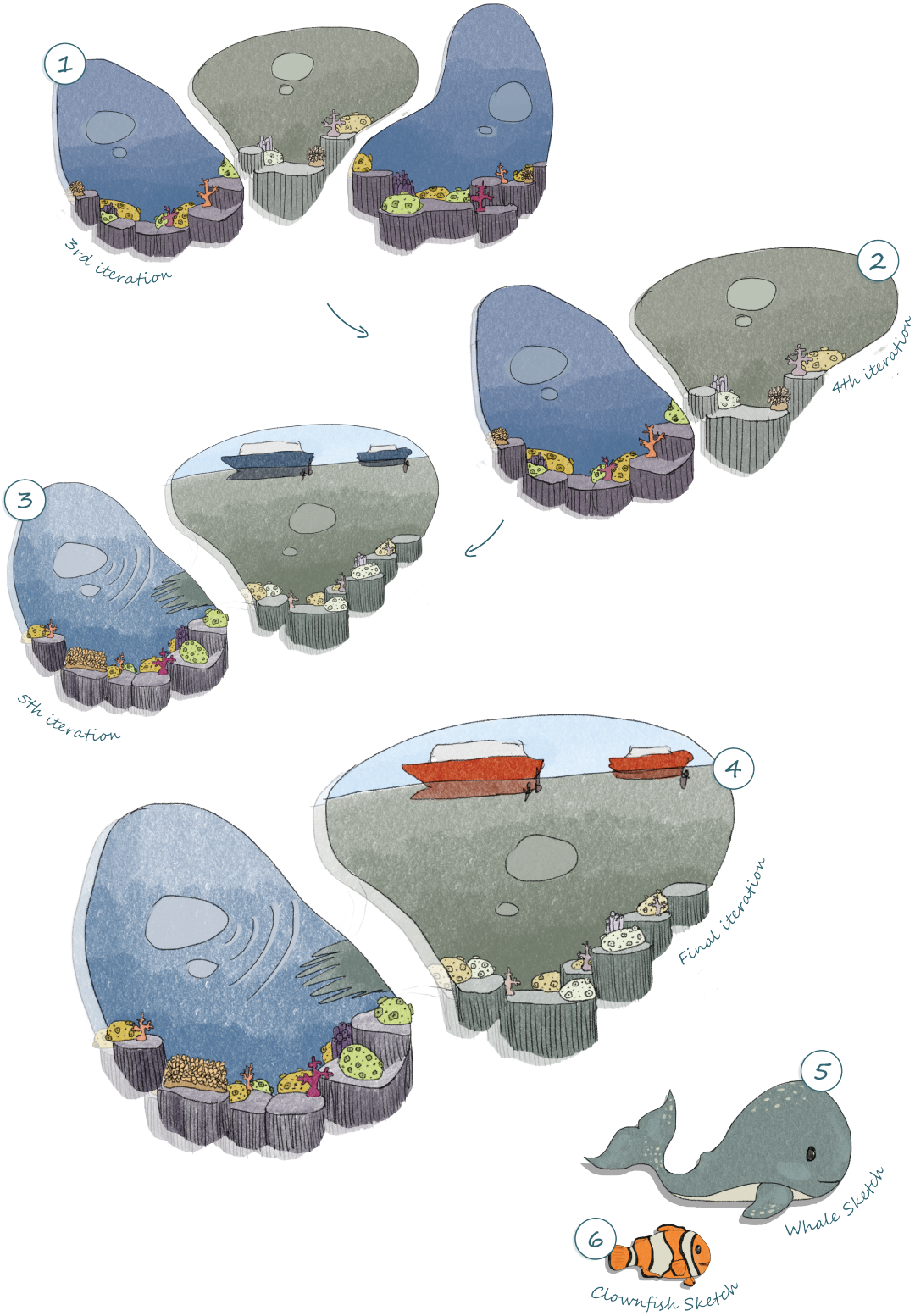

Fig. 11. Iterations from 3rd to the final and narrative characters: (1) Third Iteration Sketch;(2)Fourth Iteration Sketch;(3)Fifth Iteration Sketch;(4) Final Iteration Sketch;(5) Whale Sketch;(6) Clownfish Sketch

are not common differences in real life, but we wanted them to have a close size. We imagined that they would be the perfect size for human hands.

3.5 Materials Experiments: Weaving and Conductive Materials

While drawing the possible tapestry's design, it was also essential to understand how the conductive materials work, how to integrate the sensors on the textiles, and how to know their limits. We decided to use Bare Conductive Touch Board (BCTB) [54] for their resources and easily applicable cases, capacity to store audio files, programming logic resources, reprogramming ability, and the results we saw in the maker community [66].

To understand the different conductive materials and how to integrate them with the Touch Board [67], we successfully tested different materials, such as copper tape, a metal clip, electric paint, graphite, and conductive thread, as seen in image 1 from Fig. 12. We also experimented with dyeing wool with diluted Electric Paint (see image 2 from Fig. 12), because it is a water-based ink that is mixable with water. We did several tests to see how much we could dilute the ink to dye the wool and make it conductive. After several trials, we discarded the idea of using dye wool with electric paint since we had no success finding the right balance.

Since we were curious to understand if the problem was the diluted ink, we decided to create several samples with diluted Electric Paint (see image 4 from Fig. 12). These samples had different levels of dilution, starting with the less diluted to the more diluted, from left to right respectively. Fortunately, all the samples were conductive.

Another ability of Bare Conductive is the capacity to use the touch sensors to detect touch proximity [68]. With two pieces of conductive thread connected to two different electrodes (see image 3 from Fig. 12), we could program the first thread to react to touch successfully and the second to react to proximity. After this proximity test with conductive threads, we wanted to understand if it would work similarly with the Electric Paint. Therefore, we painted a piece of paper with this ink and tested this sample alone (see image 5 from Fig. 12). The sample worked fine, and we felt that a bigger conductive surface better detects the proximity. So, we did the same test with two samples of Electric Paint with different sizes, image 6, from Fig. 10, which made us understand that the bigger the surface, the better the proximity detection. We also made these samples work differently, with the smaller one programmed to detect touch and the bigger one to detect proximity.

We also tested an alternative approach to using conductive thread, Electric Paint, and dyeing wool by incorporating the painted paper with Electric Paint as a sensor behind a tapestry sample (see image 7 from Fig. 12). We discovered that it works if the touch board is programmed to detect proximity rather than touch, leading to the realisation that Electric Paint sensors for proximity could replace the use of conductive threads when necessary.

It was also essential to explore various weaving samples to test the conductivity of different materials in the various weaving techniques. These experiments would help us understand how different sensors and their proximity could work together. We explored the Tabby (see image 1 from Fig. 13), Double Soumak (see image 3 from Fig. 13), Egyptian Knot (see image 3 from Fig. 13), Rya Knots(see image 4 from Fig. 13), and Rya Loops stitches by mixing them with conductive thread (see image 6 from Fig. 13). Almost every stitch worked very well, except for the Rya Knot. This stitch presented a challenge since we had to cut the wool and conductive thread. It did not

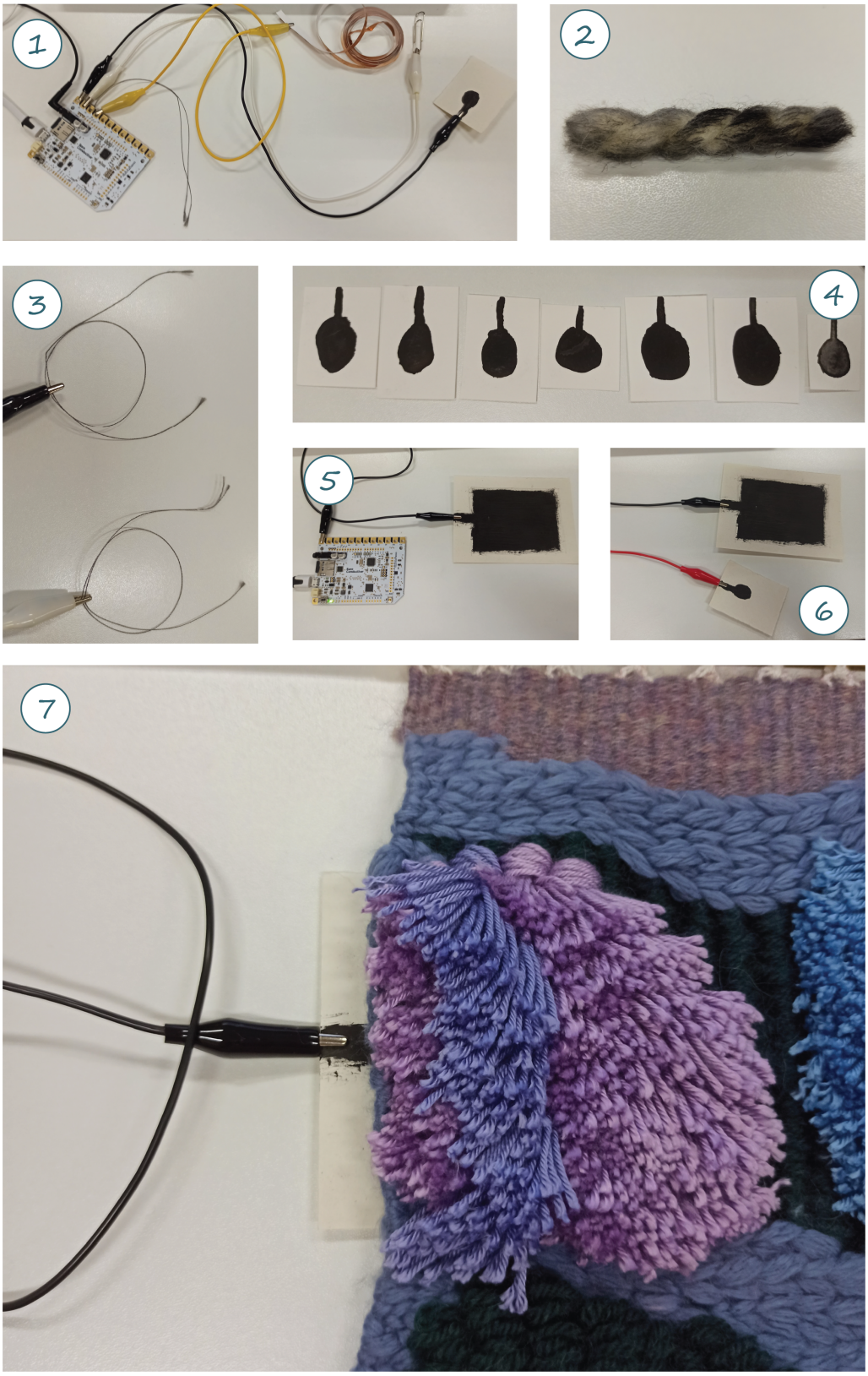

Fig. 12. Conductive Materials Samples: (1) Different Materials Tests; (2) Dyed Wool Sample; (3) Two Pieces of Conductive Thread Test; (4) Small Electric Paint Samples with different dilutions; (5) Proximity Sample; (6) Proximity and Touch Samples; (7) Electric Paint Behind the Tapestry, Proximity Test

Fig. 13. Weaving Samples: (1) Tabby or Plain weaving Samples with details;(2) Rya Loops with details;(3) Double Soumak and Egyptian Knot Sample with details;(4) Short and Long Rya Knots (Fringes) with details;(5) Felt Sample with detail;(6) Conductive Thread;(7) Conductive Fibre

work as a continuous conductive thread. To work around this, we connected each Rya Knot behind the weaving with another piece of conductive thread to make the area of the Rya Knot work as a unique sensor area.

We also created a Felt sample (see image 5 from Fig. 13) composed of wool fibre and conductive fibre (see image 6 from Fig. 13). Despite our initial concern about balancing the correct amount between conductive fibre and wool without compromising the colour and texture, we were pleased with our experiment, as the Felt worked very well as a sensor.

After testing several conductive materials and weaving samples, we concluded two things. The first one was that two different conductive threads connected to the bare conductive touch board in different electrodes could not touch each other, as it messes with the programming logic of the BCTB. So, for the final piece design, we need to place the interaction areas as far apart as possible to avoid problems with the sensing, especially as we do not know how the materials will hold together after the interaction of several users. Moreover, we also concluded that, although we successfully integrated all the different weaving techniques with conductive materials, some required more skill, patience, and attention to detail, which we had to consider regarding the final piece's time constraints.

4 Tapest[o]ry Final Design and Implementation Process

After making the conceptual and design decisions and testing materials, the following steps were to understand how to tell a story regarding marine noise pollution through an interactive tapestry. We were still up to decide which narrative we would have, how to think about the user's role during the experience, and how to adapt the narrative to the user interactions. Furthermore, we had to give life to our final design and implement all the designed components we developed.

4.1 Narrative and Symbolism Design

We aimed to use the storytelling potential of tapestries to use it as a narrative tool. This phase was about brainstorming to develop a story to answer our objective, which is capable of making people aware of the impacts of marine noise pollution. Our research taught us that whales and clownfish are examples of marine animals suffering from marine noise pollution. Since our search for inspiration, we discovered that whales and clownfish are examples of marine animals that suffer from marine noise pollution. So we thought about engaging the audience in the story of two improbable friends (a whale and clownfish) and thought their adventures show how they are affected by marine pollution. So, we decided to create this story, where these two improbable friends go on an adventure together, where we display how they are affected by marine noise pollution. We thought that giving human-like characteristics to the whale and the clownfish could humanise the impact of marine noise pollution. Our rationale is that when viewers see and interact with these characters facing big problems because of human actions, it can evoke empathy and compassion as a poignant reminder of our responsibility to protect the oceans.

We followed a simple and traditional structure to create this narrative, Freytag's Pyramid [69] (see Fig. 14). However, we wanted our audience to actively participate in the narrative to foster a deeper emotional connection, so designing the narrative had to consider the interactivity points. We can say that the story suffered several changes during the process since we had to revise the interaction points we wanted to include in the tapestry. So, the narrative flow always had to consider the user interactivity points, and the interactivity points also had to consider the narrative flow. It was a highly iterative process between this step and developing the user experience journey.

At first, we considered possibly telling the story through audio and projection. However, we concluded that the best way to display the narrative in this case was just with the audio. These audio would be the voices of our characters, which would use a direct interaction with the user while having a dialogue between them and the user. We also would use a narrator to introduce the experience and give simple instructions on starting and replacing the characters to the initial plinth. Moreover, we would have other extra characters, two humans in the ships.

This strategy aims to immerse the user in this experience while learning more about the narrative, giving him a special mission of helping the whale and the clownfish to return home.

4.1.1 The final version of the Narrative Synopsis

Our narrative tells the story of two young friends: a fearful whale and an adventurous clownfish. Both are very curious, which leads them to an adventure. These two friends finally conquered the trust of their parents to guide themselves through the sound between their houses and their school. On their first day alone after school, their adventurous side leads them into the most dangerous side of the ocean, where the water is less clear, and there is so much noise. This noise comes from

human intervention, ships, as a representation of marine traffic, a disturbing activity created by humans, and it leads the whale to harm herself and both of them to get lost. The whale and the clownfish regret their decision and try to find a solution to overcome it and return home safely. After some attempts, the two friends return home safely with the human help to stop the propellers' ships. They hope that now humans understand how they disturb their ecosystem in time to make a change and save marine life, human life, and, consequently, the planet.

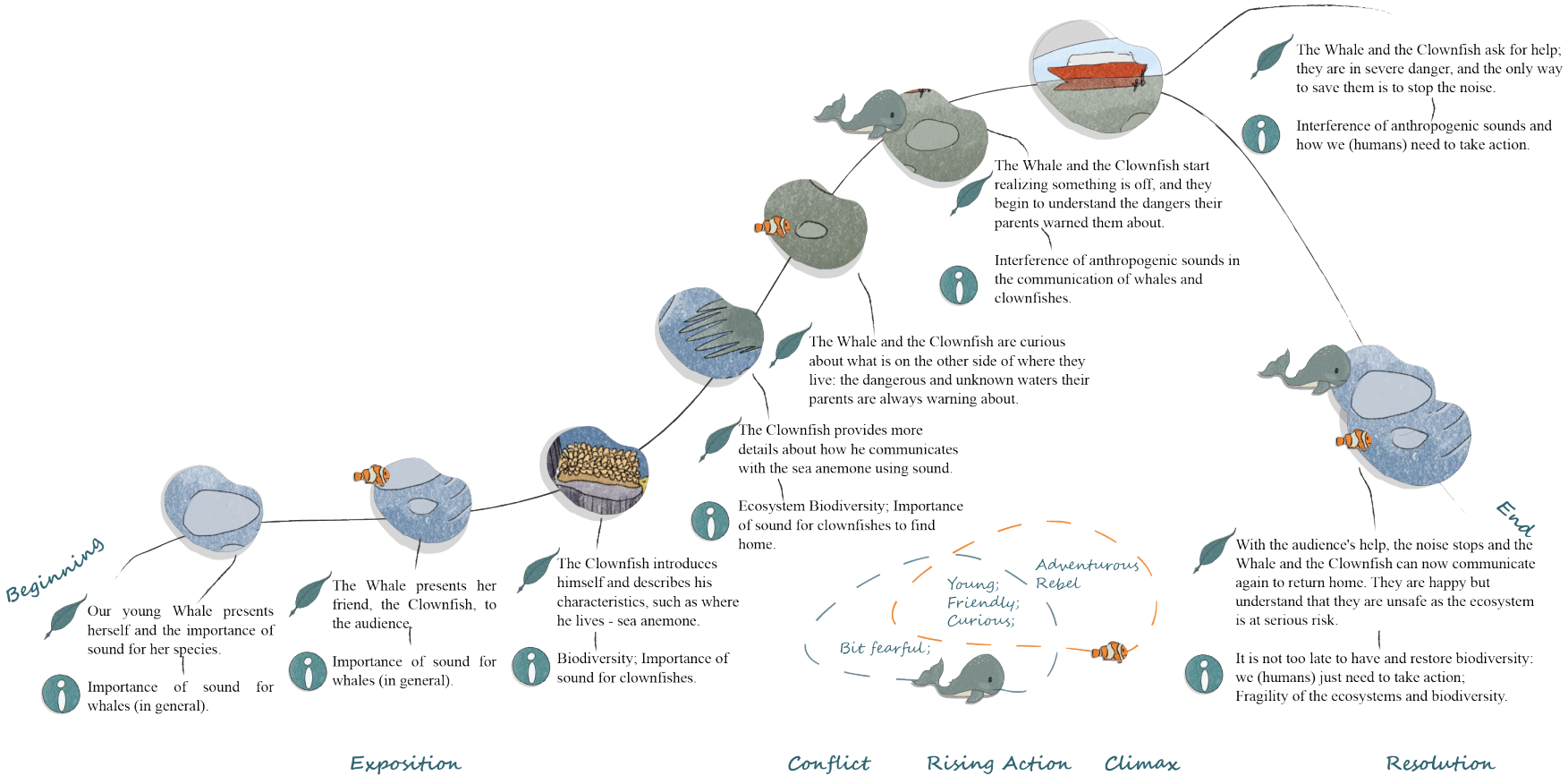

Fig. 14. Narrative flow, educational messages and characters characteristics

4.2 Mapping the user interaction, narrative and media

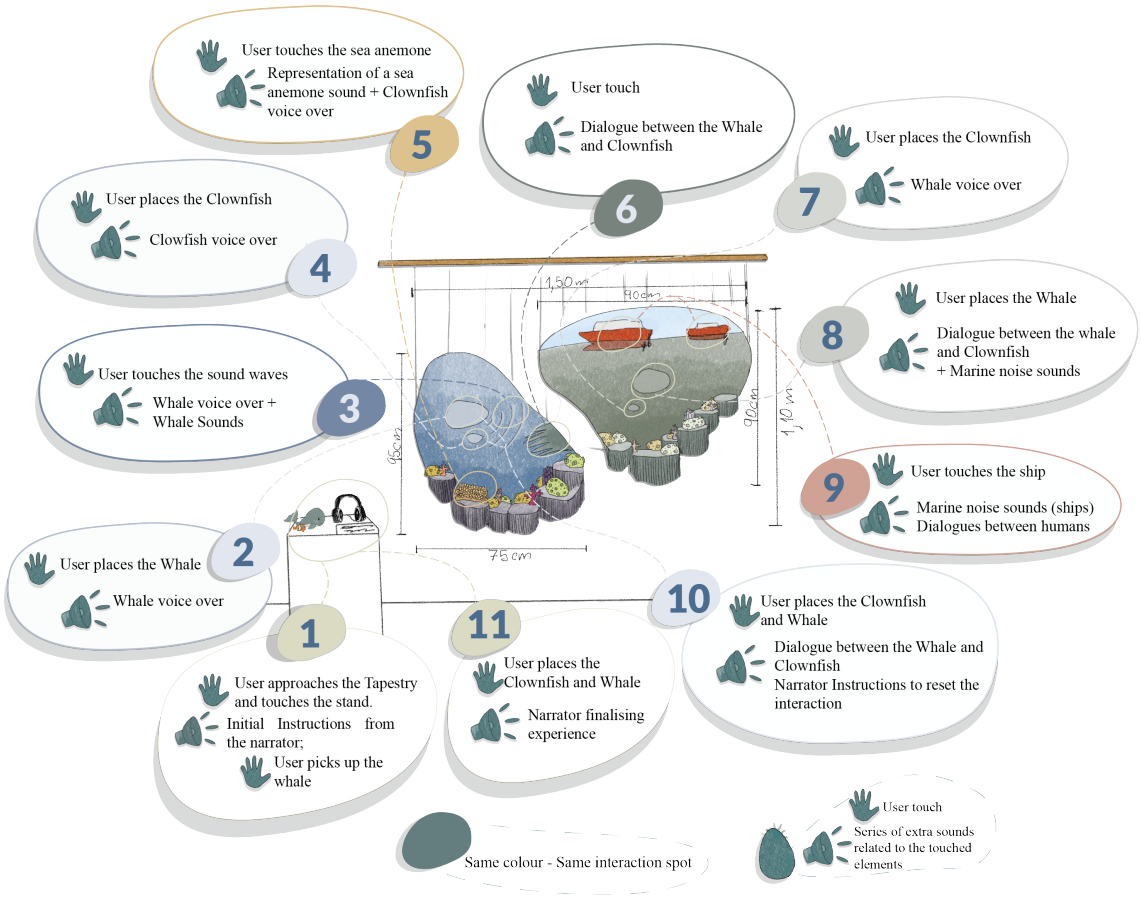

Fig. 15. Interaction order and expected tapestry size

One of the first design decisions had to do with how we had to accommodate the interaction, keeping in mind that the piece would be displayed in public spaces, like art galleries, or at environmental events to raise awareness about marine noise pollution. So, we had to think about the overall user journey from when the audience approached the tapestry to when they left, and another member came in, Fig. 15.

After creating the overarching idea for the narrative, we decided which media would be the most adequate for each moment and how and where the user would interact with the interactive piece. Another design consideration we had to consider is that the number of interaction areas had to be limited to the number of physical sensor inputs the Bare Conductive Touch Board allows.

As previously said, we had to plan the user's journey until the moment he approached the piece. So, we decided we should have a plinth, drawn in Fig.15, where we could place the whale and the clownfish for the user to take them to interact with the final piece, headphones for the user to use, and a sensor that would say "Put on the headphones and then, tap here to get started", the first interaction. In the last step of the experience, the user must place the characters and the headphones on the plinth, the eleventh and last interaction. This decision means that the

experience would start and finish at the same place, doing a reset to complete the cycle and letting another user come to use the interactive tapestry.

Throughout the experience, the audience will explore several senses while interacting with the piece, with sight and touch, to receive feedback from the tapestry. The audience must place the characters in the tapestry only after the narrative starts, promoting interaction with the piece. The user must follow specific instructions from the piece's characters and narrator to process the narrative.

At the bottom of Fig. 15, we also open the possibility of having some 'Eater Eggs', which would display extra sounds, not directly connected to the narrative but connected with the concept we built until here.

4.2.1 Interactive Paper Prototype

Fig. 16. Interactive Paper Prototype: (1)Interactive Paper Prototype; (2) Back side of the Paper Prototype; (3) The user placing the Whale; (4) The user touching a sensor

Until now, we have decided on the narrative flow and the user experience. However, we needed to ensure that our touch events, narrative, and visual design were working as we expected or if we needed to iterate them.

To help integrate the technical implementation and logic of the touch events and overall design of the tapestry, we developed a small paper prototype to test the connections to the Bare Conductive Touch Board, we printed the outline of the tapestry, and we used some Electric Paint to mark the interaction spots (see image 1 from Fig. 16). Then, we sewed some conductive thread on these marks to connect them directly to the BCTB. This way, we could quickly test the different interaction points and programming logic. We connected all the different spots we wanted to use as a sensor in the interactive narrative, making it as similar as possible to the original design. We also recorded and edited the audio files based on the narrative to know how long the experience would take. So, we could test this paper prototype by touching the Electric Paint sensor to hear the narrative (see image 4 from Fig. 16). At this moment, the experience was 6 minutes long, without counting the time the 'Easter Eggs' would spend.

To facilitate the process, we identified each piece of conductive thread sewn to the paper to find it quickly while experimenting with the prototype, (see image 2 from 16). We defined where to locate the sensors to connect them to the BCTB without touching other sensors. The spots where the user will place the Whale (see image 3 from Fig. 16) and the Clownfish on the left tapestry will need to detect their presence. So, for this purpose, these spots need two sensors to detect the presence of a conductive object, one connected to an electrode and another to the ground. The Whale and the Clownfish need a unique sensor communicating simultaneously with these previous sensors to detect their presence. In the case of the two ships, we connected them to the same sensor since, following the narrative, it will be possible to touch one or another. So, in this paper prototype, we can see the union with the Electric Paint and then with a conductive thread to connect to the BCTB.

This interactive paper prototype was essential to understand how to place the sensor through the piece. However, it had limitations, primarily because of its size. It was not easy to organize all the conductive threads, but we concluded that the best way to prevent them from touching each other would be to place the BCTB in the middle of both tapestry pieces.

4.2.2 Tapestry Techniques, Materials and colour palette

Another essential feature we had to plan was the tapestry materials, the colour palette we would use, and the types of stitches and techniques we would use in each element. This step was crucial for us to understand later what materials we would need to execute the tapestry.

The Fig. 17 displays our idealisation of each feature. Both tapestries will have several types of stitches and techniques for different visual representations. For these techniques we display in Fig. 17, we used image details of previous artworks, such as the Tabby, Double Soumak, Egyptian Knot, Short and Long Rya Knots (Fringes), Felt, Crochet and Sewn Line techniques, and another from the Wrapped Wool technique because we still have not explored it before.

The Fig.16 also presents where we would add conductive thread and conductive fibre. These places would be in the 'Characters Spots', the 'Ships', the 'Whale', the 'Whale Sound', the 'Clownfish', the 'Sea Sponges' and the 'Anemone'. It means that these elements would be interactable.

At the bottom of Fig.17, we also share our ideal colour palette for the left and right tapestry pieces and the types of wool we aim to use to create the different techniques and textures.

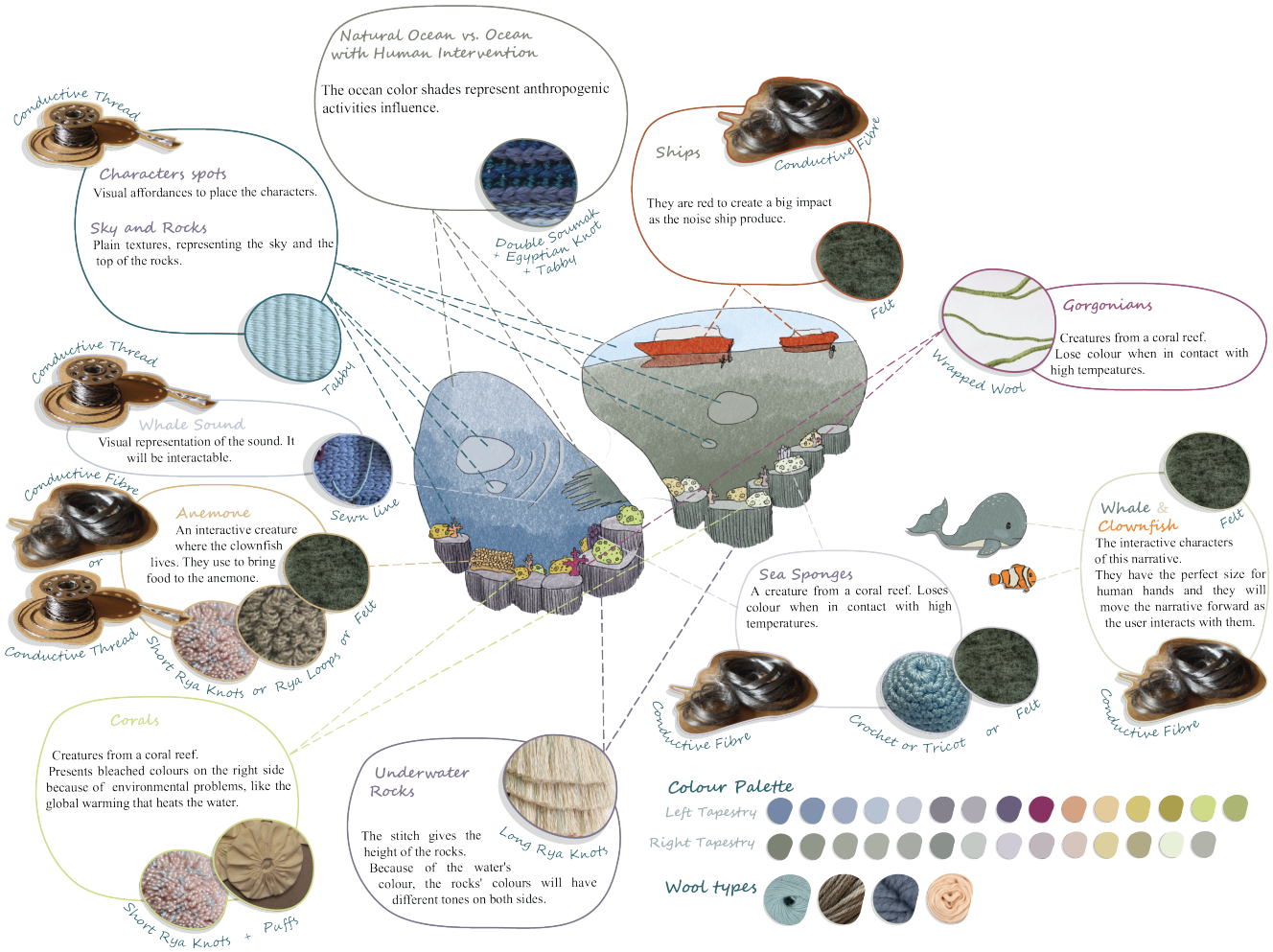

Fig. 17. Expected tapestry techniques, materials and colour palette

4.3 Tapestry Execution Preparation

This section will explain all our procedures, from acquiring the wool we needed to execute our project to the finished product.

4.3.1 Wool acquisition

We already had a final study, and we had decided on all the colours and textures we wanted to include. So, we only needed the materials to start this project.

Our first idea was to ask for help from the community. We wanted to add to the concept the contribution of recycling and reusing materials stored at home for years without using them, giving them a new life and promoting a healthier planet. For this purpose, we created a post to share on social media, hoping to receive some wool donations for this project. Some people gave us material, which was a precious help, but the quantities were insufficient for our planned project (see Fig. 18).

Fig. 18. Some of the wools we received from the community

At that time, we came up with another idea to acquire more materials. We asked for the help of a local institute, Instituto do Vinho, do Bordado e do Artesanato da Madeira (IVBAM), which is responsible for coordinating, defining, regulating, and executing policies of valorisation and preservation of several traditional and cultural heritage produced in Madeira Island, such as Vine, Wine, Madeira Embroidery, Crafts, and Spirits.

Madeira has a strong bond with the needlepoint tapestry. Many Madeirian people, generally women, worked as crafters of this technique, creating flowers, faces, landscapes, and reproductions of paintings. Later on, around 1850, this technique was industrialised and grew in the number

of crafters and businesses. This evolution, by 1938, brought new applications of the needlepoint tapestry, such as bags, carpets, cushions, seat covers, and wall hangings.

Even though the technique grew so much during that period, after a presentation of our project to IVBAM, we learned that, nowadays, the number of crafters has reduced through the years and is a subject of worry for them. The needlepoint technique was of considerable interest but somehow lost its strength. Moreover, as they said, they also want to introduce new tapestry techniques to revive the craft world of Madeira, and one of them is the type of weaving we are working on in this project, free weaving. They showed their interest in this project due to its nature. It revives a craft technique from a modern perspective, associating it with technology. It might enable the continuity of artisanal techniques with a modern twist and raise interest in new generations.

Fig. 19. IVBAM Woll: (1) The samples of wool we wanted to ask to IVBAM;(2) The wool IVBAM gave us.

Since IVBAM saw potential in this project, they agreed to collaborate with us to cede some wool from their private stock of wool. From that moment, we shared a document with them, including all the planning for the colours and types of wool we needed. We created a sheet with samples of the colours we wanted and the written quantities we expected to use, together with IVBAM (see image 1 form Fig. 19). Later, they contacted us to give us a selection of wools from their private collection (see image 2 form Fig. 19). This wool was Sotave Wool brand, a thread with around 4 mm of thickness, the wool that the needlepoint technique uses. With this help, we covered most of the quantities needed to execute our project.

This help was quintessential for the execution of our weaving tapestry. Although this collaboration was crucial, we needed some fabric for coral details and wool roving for the felting elements. We could not gather these materials from donations and collaborations, so during the execution of the final tapestry, we ended up deciding to buy them.

Some conductive materials, such as conductive thread and conductive fibre, used in this final weaving were the same as we used in the primer experiences. We bought new alligators to connect the elements to the Bare Conductive Touch Board.

4.3.2 Wool Preparation

Simultaneously, we were preparing our wool. As we already said, from our first idea of acquiring materials, we received some donations of wool. This wool took a phase of selection before being used. We had wool with much dust, entangled wool, and different quantities, colours, and thicknesses, image 1 from Fig. 20. The first step was cleaning it by shaking it in an open space to remove most dust and leaving it airing for some time. While cleaning, we separated them by colours, tonality, saturation, and thicknesses so it would be easier to find them later, image 2 from Fig. 20. After some time, we started winding the wool and leaving it inside boxes separated by colours to have them organised and nearby while working on the weaving. This step was necessary for the organisation of the upcoming weaving process.

Fig. 20. Wool Preparation: (1) The wool before the cleaning process;(2) The wool after the cleaning process.

After these wools from the donations organisation, we also had to prepare the IVBAM wools to work. For that purpose, we used an improvised machine made of bench feet, an old bicycle wheel, some pieces of wool and screws, image 1 from Fig. 21. This machine helped us to unwind wools into small card rolls, image 2 from Fig. 21, making it easier to work in the following steps.

While we started to weave, we received our purchases of wool roving, a selection of colours for the anemone (tones of oranges), ships (tones of red and beige), the whale (tones of blue, green, beige and black), and the clownfish (tones of orange, beige and black).

4.3.3 Preparation of the weaving frame

The first step to start weaving was the building of the structure. Since our weaving needed ample space to work and we did not have a proper structure, we built our frame (see image 1 from Fig.

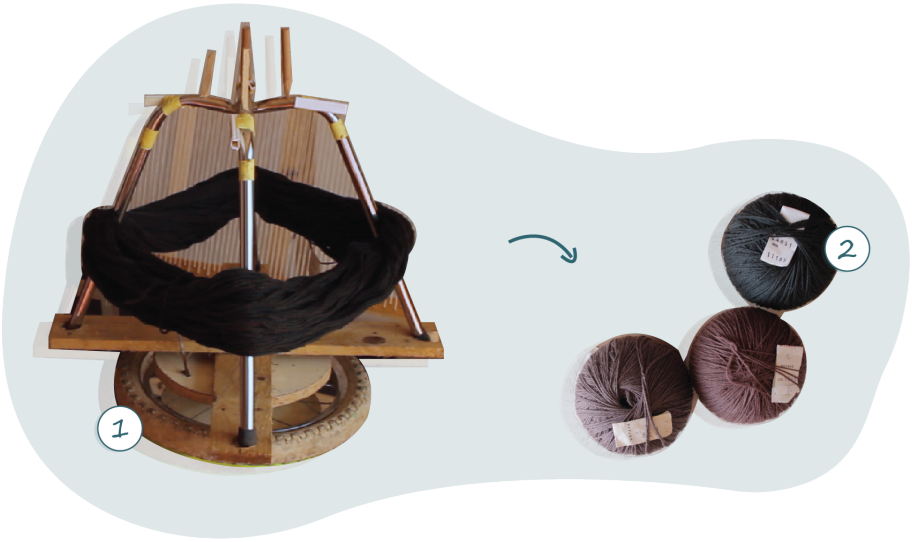

Fig. 21. Unwinding Wool: (1) The improvised machine; (2) The wool in the card rolls.

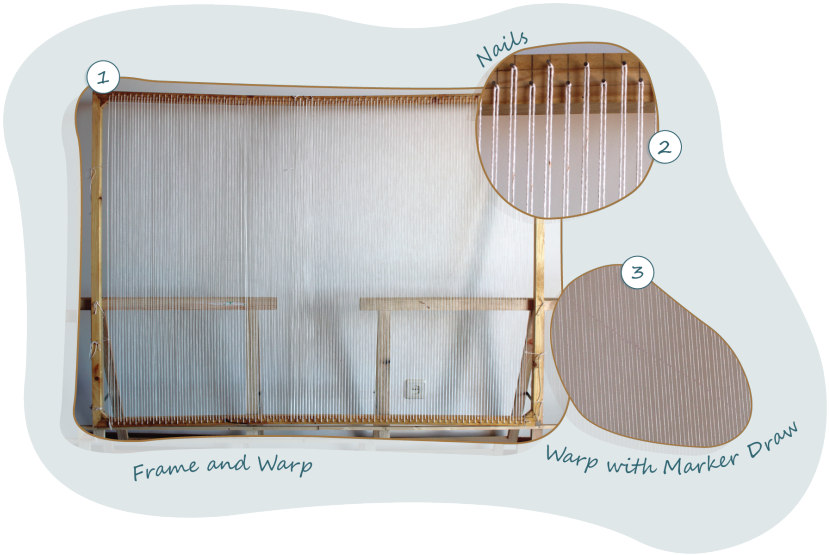

Fig. 22. Frame Loom: (1) Frame loom Structure with the warp; (2) Nails; (3) Warp with the marker draw

22). We decided that a frame with 1,60m x 1,20m would be the perfect size to develop both pieces. This frame consisted of four pieces of wood to create a rectangle with these proportions. We also added nails to hold the first threads. While weaving, we wanted the space between the warp thread to be equal, so we meticulously nailed them to the wood with 1 cm of distance (see image 2 from Fig. 22).

We also thought that a frame of this size should need one or two more pieces of wood in the middle to hold the structure, preventing it from changing the structure size. However, we tried to do the warp without any more pieces of wood. Furthermore, we first considered creating two separate warps inside the same frame loom since we had two weaving pieces. Unfortunately, as we already expected, it happened. Pulling the thread was tightening the frame more and more. So, we had to step back and fix it before starting to weave. To fix the structure, we had to remove the thread we had placed before to have enough space to place the new piece of wood. This piece of wood was crucial to hold the initial structure, preventing the frame from reducing its first size (see image 3 from Fig. 22). Since we had a fixed frame loom, we could do the warp again, with a change of plans, a unique warp for both weaving tapestries.

With the warp ready, the next phase was understanding how to transfer the same drawing we did on the final study to the warp threads. We had to draw for the format and size of the new frame loom. We thought of two different ways to do this. The first was to draw directly on the warp thread with a marker and nothing to guide. The other was to upgrade the drawing first and then, from this one, draw on the warp thread using that drawing as a guide. Our strategy was a mix of both strategies. We first upgraded the final study to an improvised paper with the exact size of the frame loom. Then, after finishing this big drawing, we cut the outside shape of both pieces and used it to guide us to draw on the warp thread with markers, similar to a stencil. After having the outline of both pieces, image 3 from Fig. 22, we had to complete the inside elements' details, also with a marker, but with the first strategy, freehand drawing. As seen in image 3 from Fig. 22, it is difficult to see the drawing on the warp threads, especially on camera. Nevertheless, these drawings were essential to guarantee the proper position of the weaving pieces and their elements.

4.4 Weaving Process

Usually, we start the weft from the bottom to the top of the warp. The weft is composed of every thread we interweave with the warp thread, which, lately, will allow us to have a unique piece. We created both pieces simultaneously through small steps, divided by different stitches and areas.

Firstly, we started to create a base with a plain or tabby weave, defining the bottom shape as a substantial base to hold the next wool (see image 2 from Fig. 23). Therefore, we had to create the fringes to represent the rocks under the water.

To create the fringes (see images 2 and 3 from Fig. 23), we defined three colours of wool for each piece and a measure that later on would allow us to cut with the shape we initially wanted (see images 1 and 4 from Fig. 23). We started to divide several groups of ten pieces of thread, some with the darker colour, others with the medium colour, others with both of these, others with the lighter colour and others with the lighter and the medium colour, to fill in the suitable space and create some volume (see images 1 and 4 from Fig. 23). We used ten pieces of wool with 60 cm for each rya knot. To create the rya knot, we held the ten pieces of wool in the middle, making it seem to have twenty threads and around 30 cm.

Fig. 23. Weaving process: (1) Materials for the left side fringes; (2) Fringes base, fringes and top of the underwater rocks form the left side;(3) Fringes and top of the underwater rocks; (4) Materials for the right side fringes; (5) Development of the healthy ocean; (6) Green area with conductive thread invading the healthy ocean; (7) Development of the unhealthy ocean; (8) Texture of the green ocean; (9) Character places on the healthy ocean; (10) Conductive Thread sensor on the character place, left side of the tapestry; (11) Conductive Thread sensor on the character place, right side of the tapestry; (12) Character places on the unhealthy ocean; (13) Development of the sky; (14) Result after creating the rocks, the ocean, character places and the sky;

Fig. 24. Corals and Sound Waves: (1) Yellow materials for Rya Knots, Left piece; (2) Green Materials for Rya Knots, Left piece; (3) Left piece corals' development; (4) Yellow materials for Rya Knots, Right piece; (5) Green Materials for Rya Knots, Left piece; (6) Right piece corals' development; (7) Corals; (8) Detail of a left piece coral; (9) Detail of a right piece coral; (10) Sound waves development with roving wool and conductive thread; (11) Sound waves coming from the whale place.

After the fringes, we built the top of the underwater rocks (see images 2 and 4 from Fig. 23). We used a lighter wool colour, leaving space for the corals, sea sponges and gorgonians but creating shadows under them with the medium wool colour. The stitch we used for the top of the underwater rocks was the tabby stitch, which we already explained.

The next step was to fill in both pieces of seawater space (see images 5, 6, 7 and 8 from Fig. 23). We used double soumak and egyptian knots to create these areas. Both follow the idea of being darker to lighter from the bottom to the top. One represents a healthy environment, and the other an unhealthy environment. In the sensor area (see image 6 from Fig. 23), we added the conductive thread mixed with the wool threads doing the same stitch type. We left some length behind the area to connect to the BCTB later.

Then, we filled the characters' spots with the tabby weaving (see images 9, 10, 11 and 12 from Fig. 23). These forms will indicate where the user has to put the whale and the clownfish. In each area, we had to create two conductive sensors with conductive thread mixed with the tabby stitch of wool (see images 10 and 11 from Fig. 23), one to connect to the ground electrode and another to an electrode sensor. We joined two pieces of conductive thread with the regular wool thread to create these separated sensors. We used both threads alternately, and the two sensors in each silhouette were not touching. Thinking of connecting these pieces of conductive thread to the BCTB, we left some more length hidden behind the tapestry to use later.

Continuing the process, we created the sky of the right piece with the tabby stitch (image 13 from Fig. 23). After these steps, we could see both pieces' shapes and approximate how the final result would look (image 14 from Fig. 23).

Moreover, we decided to create corals in this phase, with the short rya knots (pompom-like texture) mixed with puffs (see images 3, 6, 7, 8 and 9 from Fig.24). These short fringes are similar to the long fringes, except we use a different way to make them. First, we cut several pieces of wool around 10cm long (see images 1, 2, 4 and 5 from Fig. 24), using a piece of cardboard as a measure. This cardboard helps to cut more pieces of wool at a time, all the same size. Then, we did these stitches by making the rya knots on the warp thread. These corals have another different thing than we made before. We mixed puffs with them. We will explain how we did these puffs at the 4.5 section of the tapestry. We added these puffs to the piece with a regular sewing thread, alternating it with the knots. It gives a different volume and texture to corals.

Therefore, we started to see the best strategy to add the sound waves from the whale (see images 10 and 11 from Fig. 24). The idea became similar to what we thought in the final study, except we did a soumak weave stitch over the blue sea with roving wool and conductive thread. This way, the sound waves will allow us to have a new sensor to connect to the BCTB.

4.5 Non-weaved Elements

Even though the weaving seemed almost finished, we had the most complex steps to develop. This phase was complex mainly because we had not previously worked with some of these techniques or had not practised enough to do it quickly. We developed techniques such as crochet, fabric manipulation, and manipulating wire to surround with wool elements. We also created dry felt elements. We developed all these components simultaneously with the weaving process.

4.5.1 Crochet: Sea Sponges

The first non-weaved technique we explored was the crochet to create the sea sponges. We did not have that much experience with this technique, so it took us some time to learn and develop it better. The sea sponges were composed of several different-sized pieces of crochet.

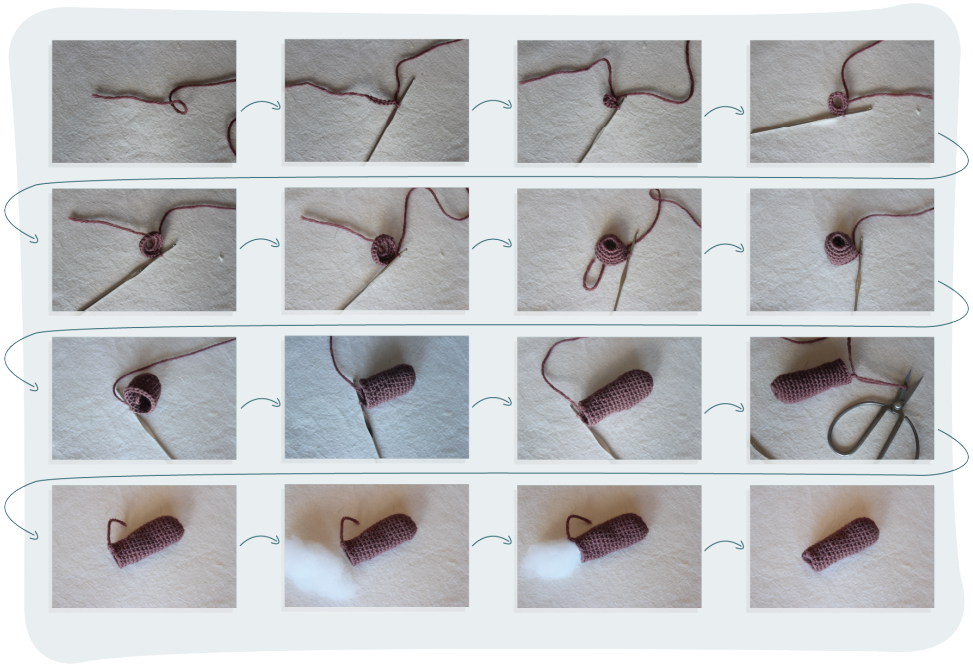

Fig. 25. Crochet process for a piece of a Sea Sponge

Each crochet sea sponge followed the same development logic (see Fig. 25). We started by creating a chain of eight stitches. We closed this chain to create a circle that lately became a hole on top of each piece of the sea sponges. Therefore, we used the circle to hold the next stitches. We started by adding sixteen new stitches to create an initial row. We wanted to increase the size of the top of the sea sponge, so in the first row, we gradually increased the number of stitches, adding one stitch after each of the four stitches and increasing the number of stitches to twenty. We followed the same logic on the next row, adding one more stitch after each of the four stitches and increasing the number of stitches to twenty-five. After increasing the size of the top of the sea sponge, we maintained the number of stitches to create its length. Gradually, we started to reduce one stitch after developing several rows to reduce the bottom size of the sea sponge. The number of rows was not precise because we did several different sizes of sea sponges. So, we adjusted the reduction process, thinking about the final size we wanted for each element. Ultimately, we cut the thread and filled the element with filler acrylic past.

As we already said, we wanted to develop two different versions of the ocean, where the left piece wants to represent the good version of the sea, and the right piece the bad one. Having this in mind, we thought that a great way to display this difference was to change the colours of the right-side sea sponges since they lose their colour when in contact with warmer water. For the left tapestry, we did nine crochet pieces with different sizes and a more saturated colour, representing a sea sponge living in a healthy environment (see Fig. 26). For the other, we did seven crochet pieces

Fig. 26. Pieces for the Sea Sponges

with colour with less saturation, representing the effect of warmer waters (see Fig. 26). After we finished these elements, we sewed each component to the tapestry, one by one.

4.5.2 Fabric Manipulation: Puffs for Corals

Fig. 27. Fabric Manipulation: (1) Fabric we used; (2) Fabric circles; (3) Puffs.

For the corals, we first created some puffs with different colours to then use mixed with the short fringes. Puff is created by manipulating fabric with a sew thread technique [70].

We used four different fabric colours (see image 1 from Fig. 27), depending on the coral to which it would belong, choosing two different colours for each side. For the left side, we used saturated green and ochre yellow. Therefore, for the right side, we used desaturated green and yellow. We measured several fabric circles using a wide bottle cap to make the puffs. Moreover, we had to cut these circles (see image 2 from 27). Then, for each circle, we sewed a thread around the circle until it reached the beginning of the thread. The next step was to pull the thread, causing the fabric to bend several times while closing and creating a puff. We also wanted to keep the volume of the puff, so we filled the puff with filler acrylic paste (see image 3 from Fig. 27).

While doing the corals, we intercalated the short fringes with this puff, as we said before. To place these elements, we added a sewing thread behind the puff, doing a knot to hold itself. We used the thread to knot the puffs to the warp thread.

4.5.3 Wrapping wool on wire: Gorgonians

Gorgonians were a new experience we had not tried before. Firstly, we drew three different shapes we wanted to achieve. Then, we manipulated pieces of wire with similar shapes with pliers for six gorgonians (see images 1 and 3 from Fig. 28). This part of the process was challenging due to the wire consistency. However, this wire was the choice to hold the shape we wanted. Therefore, we surrounded and filled the wire structure with three different types and colours of wool for each gorgonian design (see images 2 and 4 from Fig. 28). We used four combinations of colours, two for the left piece and two for the other on the right side. The difference between each side was, once more, the colour saturation of the materials.

We finished these elements and started fixing them to the tapestry with wool. We tried to sew them discretely so the user did not notice the wool that held the elements.

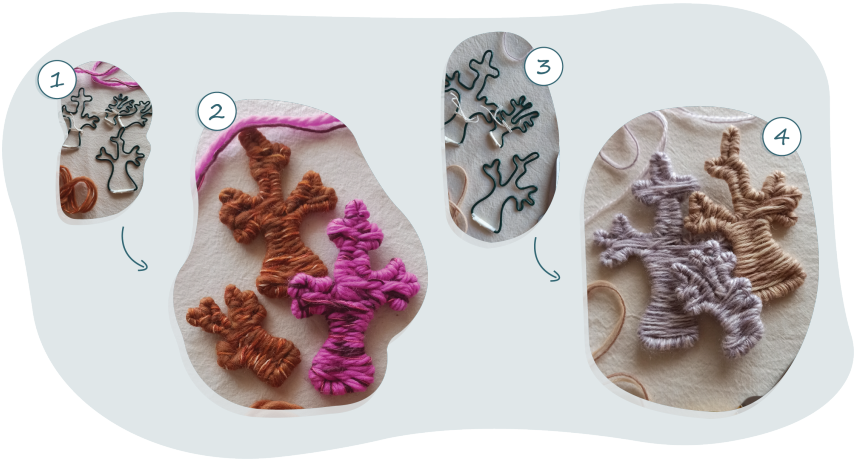

Fig. 28. Wrapping wool on wire: (1) Wire Structures gorgonians for the left side tapestry; (2) Gorgonians for the left side tapestry; (3) Wire Structures gorgonians for the right side tapestry; (4) Gorgonians for the right side tapestry.

4.5.4 Felt technique

Finished these elements, we still had an anemone, two ships, a whale, and a clownfish to create. The common ground between them is the felting technique. It is possible to use this technique in two ways: dry needle felting or wet felting, using hot and cold water with soap while using our hands to entangle the fibres. We used the needle felting technique to produce these elements in this case. For this technique, we used wool roving, which permits the use of the fibre without being winded. To execute the needle felting technique, we need a felting pad, or a thick foam, and a special needle for this type of technique. We used a thick foam to work over it and the appropriate needle for felting. To start the felting technique, we need to pull the fibre, without cutting it, from the dense piece of wool roving and star to model it with a similar shape to what we want to create. Therefore, we use the needle to felt the wool. To felt the wool fibre, we need to stick the needle

inside and out of it several times until the fibres get tangled between each other. This entanglement will create a stiff consistency depending on how felted it is. The more we felt, the stiffer the result would be. Usually, we can see how felted it is by the number of fibres still floating around the felted object.

4.5.5 Anemone

Creating the anemone was a slow process, even though we decided this element would have a small size. We first started to create the anemone tentacles (images 1 and 2 from Fig. 29). We added orange fibre and mixed it with conductive fibre to create a sensor on this element. We made each component of the anemone alone to join them afterwards. For each element, we tried to manipulate these fibres with our hands, creating the shape we wanted. After having a similar shape, we started to use the felting needle. The idea was to make the fibres tangle so they no longer separate.

The first element we did was a tentacle. Therefore, we had to test it to see if it was conductive. The tentacle worked perfectly, so we repeated the technique to have enough tentacles for the entire anemone. Even though we saw that the first tentacle worked perfectly, we decided to test each one to avoid problems later. All the tentacles worked as the first one, so we could continue to the following step.

Then, it was time to create the middle part of the anemone, and as we did for the tentacle, we used wool and conductive fibre. We modelled the fibre to create the shape we wanted, but this time, it was different. We gradually added wool and conductive fibres to create the volume slowly. We always left some conductive fibre out of the felted object to facilitate the object's conductivity afterwards. After finalising this middle part, we also tested it, and it was also conductive as the tentacles. However, we were still missing the outside part of the anemone.

We wanted a wool element to cover the anemone tentacles. So, we considered a rectangular shape, image 4 from Fig. 29, that could cover all the tentacles, almost creating a cylinder. So we followed the same logic as before, adding wool and conductive fibre, a quantity that we can see but does not affect the colour of the final aspect of the anemone.

At this moment, the next mission was to join all these elements together. We could sew all of them together. Happily, the advantage of this technique is that we can felt each piece to the others with the felting needle, so it is always possible to add more elements if needed. We started with the middle element and the tentacles. We felted each tentacle one by one around the middle element, filling it all around (see image 3 from Fig. 29). After having all the tentacles felted to the middle element, we tested its conductivity, using an alligator to join all the fibres. We tried to touch it in different places, simulating the possible touches of future users, and apparently, all the places were conductive. Therefore, we started to add the cover element (see images 5, 6 and 7 from Fig. 29). We tried to model it to create smooth curves to make it similar to an anemone. While trying to model these curves, we also tried to connect the fibres from the cover layer to the interior of the anemone. After finishing the felting process, we tested it again to ensure all the possible touches and gestures the user might make were detected. With a great result, we were able to continue the process. After we finished this phase, we added a conductive thread to connect the Anemone to the BCTB (see image 7 from Fig. 29).

The following step was to place the anemone on the left piece of the tapestry. Since the anemone has to continue to be conductive, we sewed the anemone directly to the tapestry with a conductive

Fig. 29. Anemone process: (1) Shaping the roving wool; (2) A tentacle; (3) All the tentacles joined to the middle component; (4) Anemone cover; (5) Adding the cover to the rest of the anemone; (6) The Anemone; (7) The conductive threads behind the anemone to connect to the BCTB;

thread. Since we will keep both pieces on the frame loom for the test phase, we used the loom structure to hold the conductive thread, separating it from the other conductive threads. We had to connect the anemone to a different electrode than we expected to avoid the threads from touching each other. We have connected it to the E7 electrode on the BCTB.

4.5.6 Ships

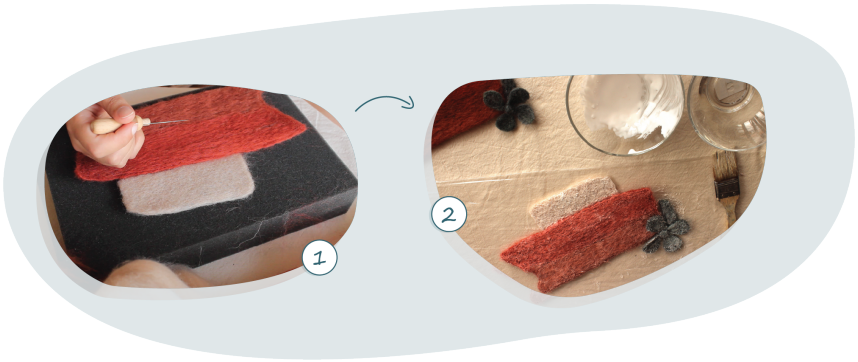

Fig. 30. Ships: (1) Felting a Ship; (2) Creating a rough texture with white glue.

An important concept we wanted to give the user with the ships was the interveinance of human actions on the marine environments, such as the anthropogenic sounds. As previously said, we want to create an uncomfortable solution for eyes and touch. In our final study, we already decided the ships would be red, which creates a stark contrast. This contrast aims to call for the user's attention since it is in the middle of low-saturated colours. In the case of the texture, we had some difficulties to choose and create a rough texture. We first considered using a material that seems rough to the touch and mixing that material with the roving wool. The texture seems plastic-based, which, from our perspective, contributes to the concept of human intervention in marine environments since much marine pollution is plastic because of wrong human actions.

So, we started using wool and conductive fibres to create a ship, using fibres in different directions to ensure they better tangle (see image 1 from Fig. 30). As we did on the anemone, we used the needle felting technique. The ships' dimensions were a constraint since felting took us more time than expected to execute. While we were felting, we tried several times and ways to add the plastic material we chose before, but it was not working as we expected, so we changed our mind.

Meanwhile, we were developing the propellers for the ships. The first attempt went wrong. We mixed two wool fibre colours to have the desired colour, but the result was too dark. Because of that, we repeated the process, adding another colour, a green tone of blue. This choice made the result look lighter, closer to what we imagined.

While developing the propellers, we searched for other materials to replace the material with the rough texture, a material with the regular aspect of being made of plastic. However, the other materials did not have the texture or the characteristics we wanted. The only possible material was white glue, changing the wool texture to a weirder and plastic-like texture.

Nevertheless, we were not sure that this type of procedure would work. So, we had to test it in small samples. Since the first propellers we created did not work, we used them for small sample tests. So, we decided to use them to test the white glue and its effect on the wool. A constraint

we were also thinking about was its conductive potential. The first samples had conductive fibre, so we tried to add white glue directly on one sample and white glue mixed with water on another. Both samples worked as expected, and we decided to use white glue without water after analysing the texture roughness of both samples. The next phase was to add white glue to the ships with a pencil, making it absorb it (see image 2 from Fig. 30).

4.5.7 Our Characters

We decided that our characters would be felted objects. We used the needle felting technique to execute this phase like the previous elements. Since the user should grab these characters, we wanted them to have some volume. However, we wanted to place these characters on the tapestry, so our idea was to have a plain surface behind the character while the front of it had volume. What was still up to decide was the strategy of placing the characters on the tapestry during the user's interaction.

4.5.8 Echo, the Clownfish

One of our characters is the clownfish, a tiny and friendly fish. Until now, we had no idea about its name, so we searched for names related to sound and found the name Echo, which is entirely related to sound [71]. We inspired ourselves with real pictures and drawings, such as the character "Nemo" from the Finding Nemo movie from Disney Pixar [72]. Moreover, as previously said, we used the felt technique to create our characters. We started the procedure by choosing the roving wool colours we used on the clownfish.

The following step was creating a base shape with white roving wool and conductive fibres, image 1 from Fig. 31. For this phase, we focused on the body shape without the fins. For that, we had a printed drawing we had previously done. The result is always an approached shape of the drawing. As we did before, we tested if this shape would work for a presence sensor, and it had a great result, allowing us to add more fibres.

The following fibres were to create the body volume with tones of light orange (see image 2 form Fig. 31). During this step, we did not use more conductive fibres since this element is supposed to be detected rather than touched. After having the expected volume, we started to add a new layer of a darker and brighter orange. This colour will bring more presence and attention to the clownfish.

Therefore, it was time to start detailing the outside visual of the clownfish. We first added the black with the white fibre. These stripes helped us understand the clownfish's body divisions. Then, we started to create the black stripes outside the white ones (see image 3 from Fig. 31). After the stripes, we added the eye and the mouth with black fibres and a small quantity of white to give life to the eye. We added a lighter orange wool roving fibre to create the cheek (see image 4 from Fig. 31).

After completing the body, we still had to create the fish fins. One by one, we started to model the shapes we drew in the study, using the same technique as before with the body (see image 4 from Fig. 31). We started with light orange and then detailed the fins with dark orange and black wool roving. These elements were minor, so they demanded more careful needle movements, making it more challenging to maintain the shape we wanted. After creating all the fins, we connected them to the rest of the clownfish's body using the felting needle. The final shape was similar to the drawing, with minor size differences (see image 5 from Fig. 31).

To ensure the clownfish could be detected, we tested it again, ensuring it touched both the electrode and the ground sensors. It was also working fine.

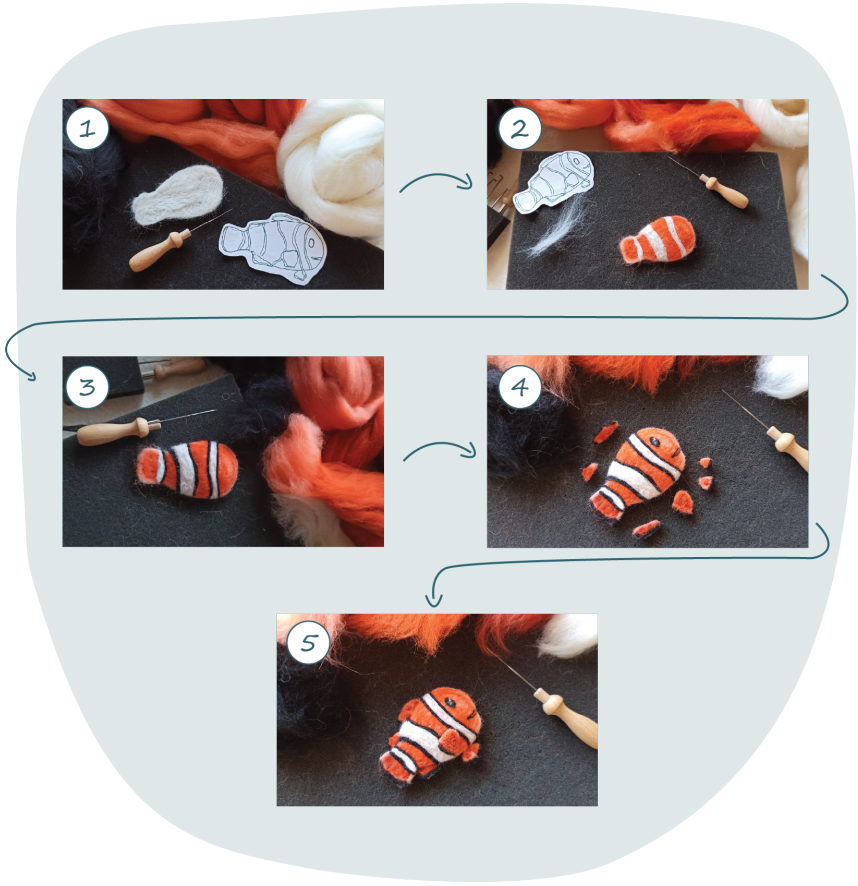

Fig. 31. Echo, the Clownfish Process: (1) Base shape of the clownfish with roving wool and conductive fibres; (2) Creation of the body volume; (3) Creation of the black stripes; (4) Creation of the eye, cheek, mouth and fins; (5) Finished Clownfish.

4.5.9 Ava, the Whale

The other character was the whale, also a child but with a bigger size than the clownfish due to its species. Moreover, it was also an element that was supposed to detect its presence on the tapestry later. Like the clownfish, until now, we had not decided the name to give to the whale. After some research, we found the name "Ava", which might mean life and sound [73]. This meaning made much sense since we are giving this whale a voice to save her life and that of other marine animals. Moreover, since the piece is about to sound, we found this to be a curious finding to enrich our narrative.

Like the clownfish, we would create the whale with the felt technique. The process started with the choice of the colours. We decided to use green, blue, white and black roving wool. Since we wanted it to be conductive, we also used conductive fibre.

As we previously did for the clownfish, we started with the white roving wool and the conductive fibre to model the shape of the whale, using the initial drawing we did before (see image 1 from

Fig. 32). Then, we tried to test the presence of the whale on the sensors, and it also worked as expected.

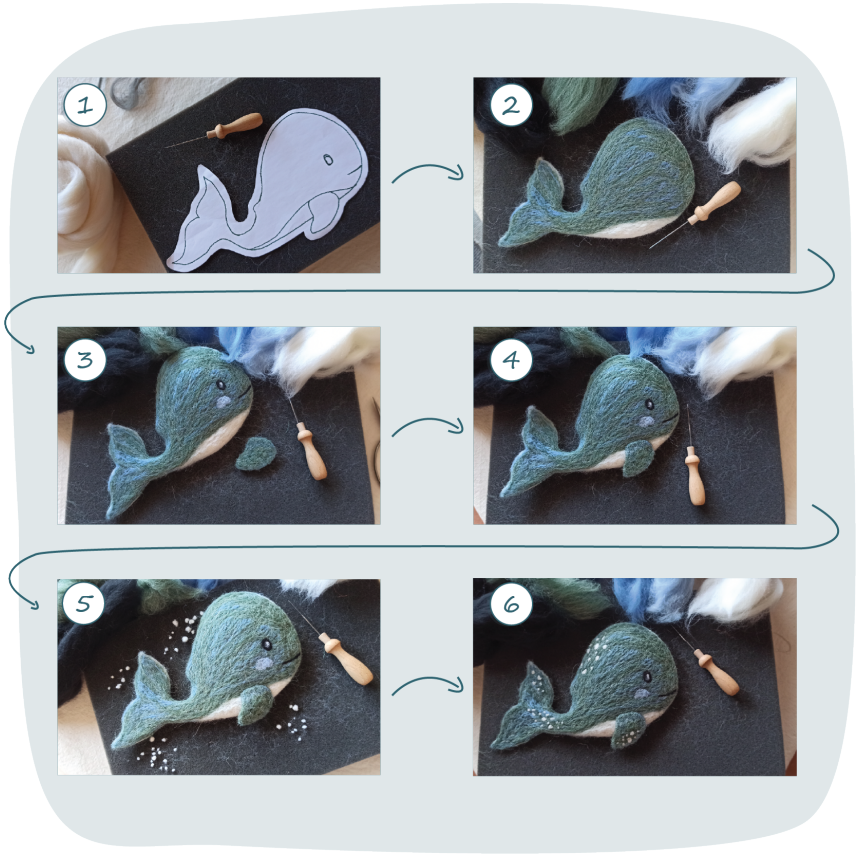

Fig. 32. Whale Process: (1) Drawing we used to guide the whale's shape; (2) Creation of the whale's body volume; (3) Creation of eye, mouth, cheek and fin; (4) Addition of the fin; (5) Creation of wool roving balls to add details; (6) Finished Whale.

After the expected results, we added more fibres to create the volume of the whale's body (see image 2 from Fig. 32). We alternated the colours using green and blue wool roving fibre for the more considerable portion of the body and white for the volume of its belly. Creating volume was challenging because the area to fill was more significant, which demanded more material and time to complete the volume we wanted.

Therefore, we had to create the whale fin (see image 3 from Fig. 32). We produced it with the same logic as before, creating the shape guided by the drawing and adding more fibres to create some volume. Unlike the previous character, the outside visual of the whale used the same materials as the interior. So, we created the eye, cheek and mouth, as we did with the clownfish, with black and white fibres and added the fin to the body (see images 3 and 4 from Fig. 32).

Then, we only had to create the details. We started to model some balls of white roving wool fibre (see image 5 from Fig. 32). These small balls were some details on the whale's body we previously drew in the study.

The final shape of the whale ended up smaller than expected, which is one of the constraints of this technique (see image 6 from Fig. 32). It is not easy to maintain the shape we imagined first.

This situation brought us some problems and made us change the whale shape on the tapestry so the whale could fit there.

Then, we had to test it again. The electrode and ground sensors detected the whale's presence as before, and we thought it was ready to use.

4.5.10 Holding the Characters on the Tapestry with Magnets

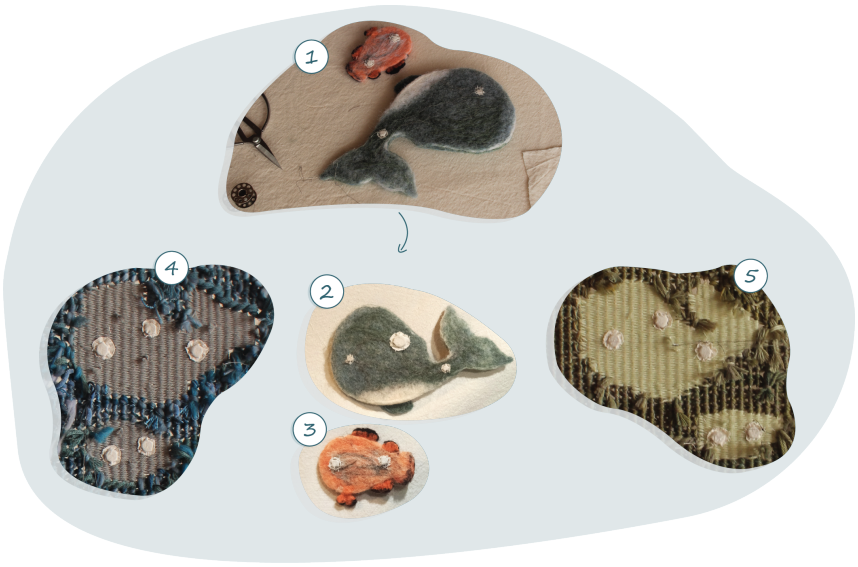

Fig. 33. Adding the Magnets: (1) Creation of the fabric pockets on the characters; (2) Magnets on the Whale; (3) Magnets on the Clownfish; (4) Creation of the pockets behind the characters' places on the left tapestry; (5) Creation of the pockets behind the characters' places on the right tapestry;

The tapestry seemed finished. Nevertheless, we had one more thing to understand. The user has to place the characters in the tapestry. It is not supposed to hold the characters during the whole experience. We thought velcro could be a solution but rapidly changed our minds. We tested, and we would pull the tapestry with too much strength, putting the stability of the tapestry in danger.

After some searching for materials, we decided to use magnets. First, we tried to understand if the strength was too much or enough. Furthermore, it seemed enough since wool in the middle of two magnets makes them lose strength but hold each other. We used two different sizes of magnets, with 1cm and 0,50cm.

To add these magnets, we also used fabric to create a tiny pocket for each magnet. We had to sew these pockets to the whale, the clownfish, and the tapestry on the characters' places (see images 1, 2, 3, 4 and 5 from Fig. 33). After adding the magnets to the characters, we had to place the magnets on the tapestry on the same direction of the magnets in the characters. Our strategy was to use pins to mark the place. This strategy worked perfectly, and we could sew the pockets behind the characters' places on the tapestry successfully (see images 4 and 5 from Fig. 33).

While testing these magnets, we saw that the two magnets for the Whale were not enough for its weight. For this reason, we added one more magnet in the middle of the Whale and on the whale's places, guaranteeing a more distributed weight (see image 2 from Fig. 33).

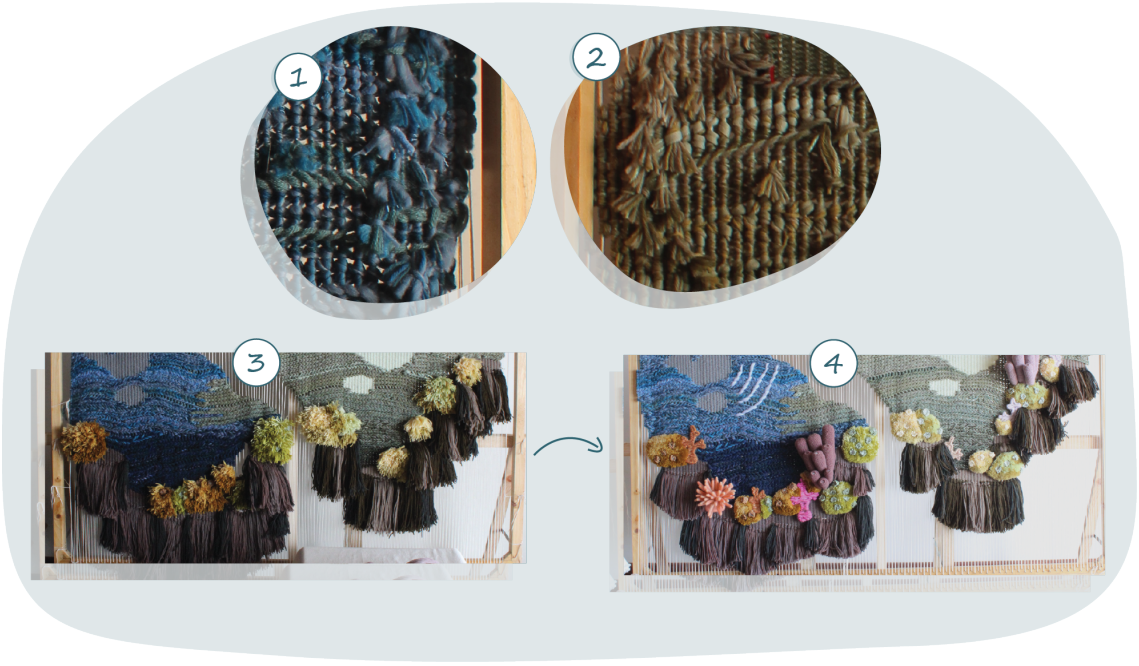

Fig. 34. Finishing: (1) Holding and hiding threads on the left side of the tapestry; (2) Holding and hiding threads on the right side of the tapestry; (3) Before cutting fringes/rya knots; (4) After cutting fringes/rya knots;

4.5.11 Finishing – Cutting and Hiding threads

It was missing some final details to have the weaving ready to connect the tapestry sensors to the Bare Conductive Touch Board. We still needed to hide and hold the excess threads behind the tapestry, reducing the mess and cutting some fringes to make it more appealing to the eye.

We started behind the tapestry. We pulled the excess wool threads inside some weaving stitches with a crochet needle. Doing this step, we should ensure the excess is not visible on the front of the tapestry. After pulling the excess wool thread, some excess will continue to disturb the aspect of it. So, once the other stitches hold it, it is possible to cut the excess. Usually, we store the exceeding wool threads to use later on other projects. We repeat this process as often as needed to hide and hold all the threads and ensure the weaving stitches will not release afterwards (see images 1 and 2 from Fig. 34).

Then, it was time to cut the fringes of the rocks. Since we had already defined the shape of these fringes in the drawing of the final study, we used it as guidance. Sometimes, we cut some paper to help cut the fringes, but this time, we cut the fringes with scissors, looking at the drawing and the weaving tapestry. We usually use a big pair of scissors to cut more wool threads at once, which is better to accompany the hand movement (see images 3 and 4 from Fig. 34).

It was also time to cut the short rya knots from the corals. We used smaller scissors to cut with more detail. We gave special attention to the puffs' details, cutting the wool surrounding them shorter and gradually leaving longer wool threads around. The idea was to make the corals look more roundish and fluffy (see images 3 and 4 from Fig. 34). After these proceedings, we could finally connect the tapestry sensors to the BCTB.

4.5.12 Additional Plinth Tapestry and Button

However, before connecting the tapestry sensors to the BCTB, we thought it would be great to have something more on the plinth to help understand the tapestry functionality. We concluded that a little tapestry, where the whale and the clownfish will start this journey, might help and make the user understand the following interactions. This idea was about creating the same characters' shapes we did before on both tapestries to help comprehend where to put the characters (see images 1, 2 and 3 from Fig. 35).

We followed a similar process from the first weaving tapestries, starting to draw with the same size as our weaving. However, it was different since we used a more petite weaving loom frame than the previous one, without nails. We cut thirty threads to create the weaving warp structure. We added these threads, one by one, separated from each other, with 1cm of distance. Above this warp, we drew with a marker what we drew in the study.

We started the weaving with the tabby weaving stitch to create the base for the fringes. Therefore, we did the fringes following the same logic as the previous left tapestry, with greys with tones of purple. Then, we created a green coral with the knots and the puffs, the same as before. After having the fringes and the coral, we developed the ocean with double soumak stitches, as we did on the first tapestry. Finally, we filled the whale and the clownfish's shapes with the tabby weaving stitch with wool and added the conductive thread to create the final sensor.

We also added an initial button to start the experience. We did a small pompom with rya knots for the starting buttons, separated from the other piece (see image 4 from Fig. 35). The difference between these rya knots and the previously done ones was that we added at least two pieces of conductive thread of the same size as the wool thread to create the sensor. Ultimately, the crucial thing to do is connect each rya knot with one piece of conductive thread to use the whole pompom as a unique sensor. We connected the button sensor to the E1 electrode of the BCTB. It has the mission of ending and resetting the experience. This button will have a message pointing to it, asking the user to touch it after putting on the headphones.

4.6 Technical Implementation

As said before, we first thought the logic of using the sensors would be completely linear. However, we had to change this logic due to the positions of the threads, something we noticed with the paper prototype, but we thought that would be easier to solve in the tapestry on the final result.

Our flow chart follows a linear construction of waiting for the user's touch, receiving the user's touch, reproducing the audio file, locking the touched electrode, and waiting for the touch on the next electrode. However, we have some critical variation key points that use different actions. When the user returns to the left tapestry with the characters, the code must analyse if the user placed the whale and the clownfish on the tapestry by detecting their presence. The flowchart is available in A Appendix.

We added the edited audio files to BCTB in an mp3 format, the only format the BCTB reads. The audio files follow a sequence from 0 to 10, and the BCTB displays the audio files according to the user interaction. However, no audio will play when the user touches a sensor that does not follow the order of the predetermined interactions, meaning the user must always follow the instructions given through the audio.

Fig. 35. Plinth Tapestry Pieces: (1) Additional little plinth tapestry; (2) Plinth tapestry top view with characters; (3) Plinth tapestry front view; (4) Initial button sensor;

In this phase, we received technical support from a bachelor's student in informatics engineering, Francisco Oliveira, who contributed to the technical implementation and programming logic with the Arduino IDE software.

4.6.1 Audio Records and Editing

After finalising the physical phase of the project, it was time to record and edit the final version of the audio files. For this purpose, we decided to record in a meeting pod, which reduces the surrounding noise and gives us better-quality records. We also needed five voices: one for the narrator, another for the whale Ava, another for the clownfish Echo, and two for the humans on the ships.

We created a guide explaining each character's personality and the dialogue between characters, including details of the expected user's interaction. As previously said, we defined the interaction elements, so we had to record audio for each tapestry interaction, following the narrative and dialogue created before.

We decided to plan a strategy for recording the audio. We recorded the voices individually when the characters had a monologue. However, when the characters were having a dialogue, we decided to record simultaneously instead of separately to join the records during the editing process. This decision had reasonable logic since the dialogue seemed more natural when recorded together, avoiding the change of voice intonations and keeping the dialogue flow. All the guide used to the audio record is in B Appendix.

For the audio edition, we searched for free sounds, like whale sounds, coral reef sounds, ship noise sounds, and the ocean soundscape. We aimed to create a complete underwater environment emphasising the importance of sound for marine living beings and how sounds introduced by man disturb them.

When we had our records and the extra free sounds we found, we started to edit the audio files with the help of Adobe Audition. This tool allowed us to reduce some noises, cut unsuitable audio parts, and add several sounds to play together. We also decided when to use a higher audio than another and vice versa. The idea was to harmonise everything to sound natural and impactful. We wanted the user to understand the characters' words and transmit their emotions.

4.6.2 Connections to the Bare Conductive Touch Board

With the programming logic implemented and the audio files ready, we needed to test the final connections with the BCTB. When we tested with the paper prototype, we used the conductive thread connected directly to the BCTB. However, we wanted a solution to make it easier to connect and disconnect because we might need to transport the tapestry to several different places, and it would be great to remove the BCTB, preventing damage. We decided to adapt alligators to the conductive threads from the tapestry sensors.

Fig. 36. Connections from the tapestry to the BCTB: (1) Back side of the interactive tapestry with the connections to the BCTB; (2) Conductive threads positioning; (3) Alligators connected to the BCTB.

The alligators that came with the BCTB we previously used to test the conductivity of our sensors did not have enough length for this tapestry. So, we had to adjust the BCTB connections to our project. The conductive thread is one of the great solutions. It allows us to create long connections because of its flexibility and without creating significant visual wire confusion because

of its size and thickness. We made our wire alligators with the BCTB by buying several alligators with wires, deconstructing them, and building new ones by replacing the old wire with conductive thread (see image 3 from Fig. 36).

We first thought of following a linear order with the sensors. However, thinking about the intersections, we had to change this order. The threads could not touch each other because it would cause them not to execute the actions. So, we positioned the BCTB in the middle of both tapestries, hidden behind the tapestry on the right side, to have a minimal length of conductive thread for every sensor (see images 1 and 2 from Fig. 36).

We kept the weaving tapestries on the weaving frame loom for the testing phase. Since it had a piece of wood in the middle of the structure, we used it to place the Touch Board microcontroller (images 1, 2 and 3 from Fig. 36). Even though we expected everything to be in place, while adding the code to the Bare Conductive Touch Board, we got new problems. We were unsure if it was because of the threads' proximity or the proximity between alligators. So, we tried to disconnect and reconnect them to understand what was failing. From what we understood, it was because the conductive threads from different sensors were too close to each other. So, we decided to create more space between the threads, holding them to the wood frame with glue tape (see image 2 from Fig. 36).

4.7 Final Interactive Tapestry

We finally finished the execution phase, which took us months of work. During the process, our initial concept ideas suffered some changes and the execution of several elements. Now that we have the final product, we can provide an overview of which materials and techniques we used (see Fig. 37 and Fig. 38).

Moreover, having the image of the final product, we can also associate the interactions to it more clearly (see Fig. 39).

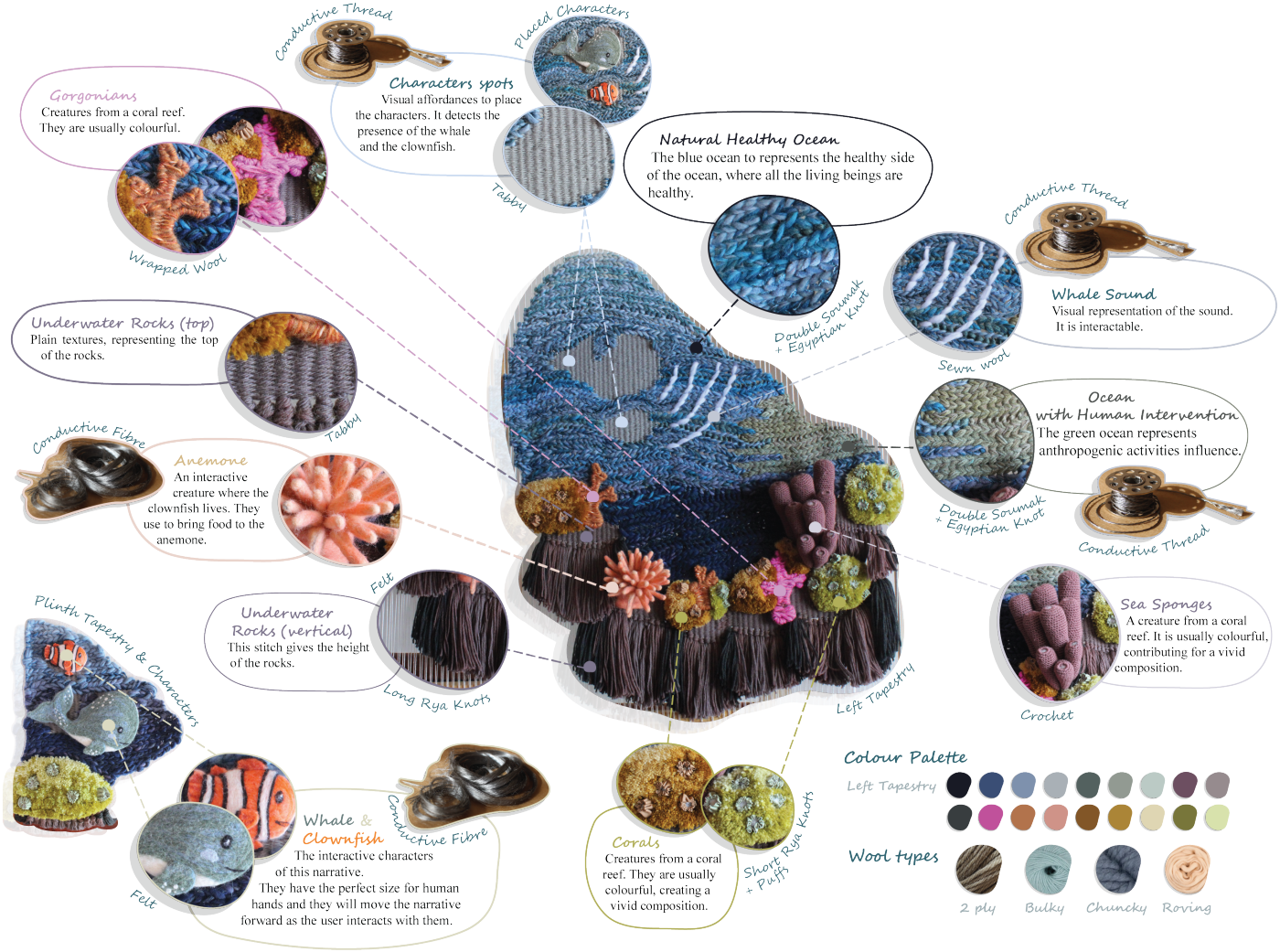

Fig. 37. Left Tapestry and Plinth Tapestry materials and techniques Overview

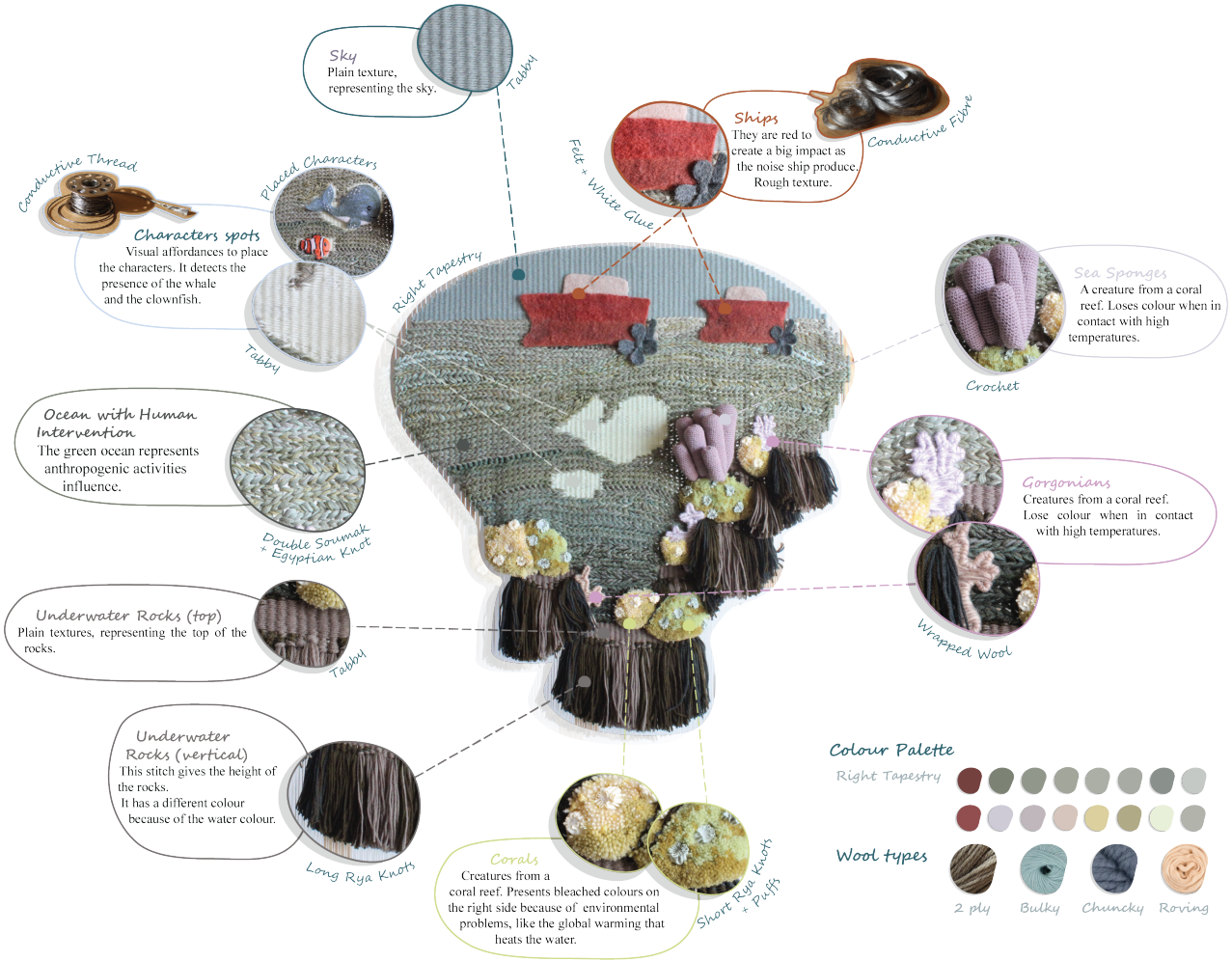

Fig. 38. Right Tapestry Materials and techniques Overview

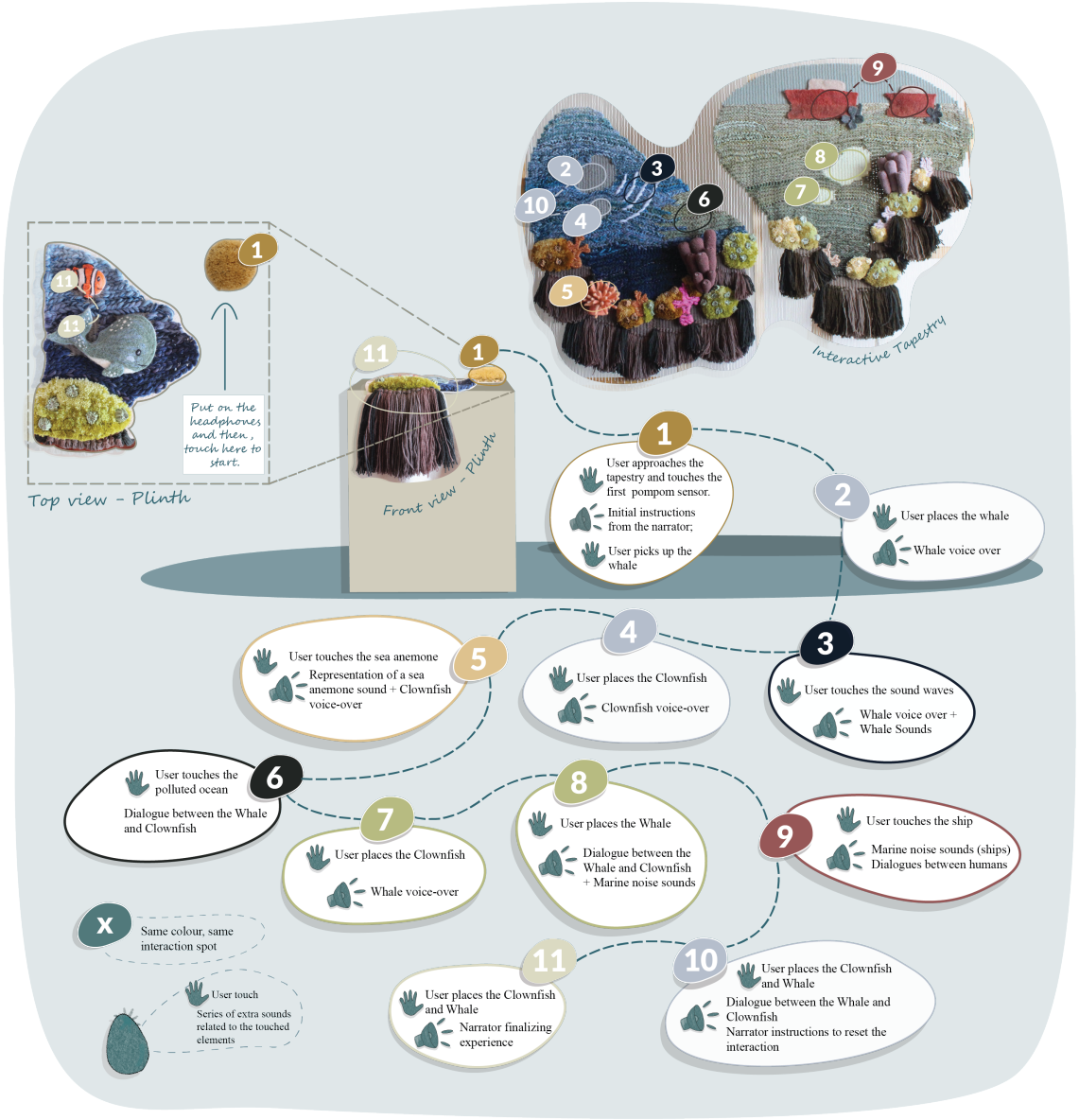

Fig. 39. Final Interactions Overview

5 Tapest[o]ry Prototype Evaluation

Since the beginning, these research efforts have aimed to understand if a tapestry could be a possible interface that allows the user to interact with it. Therefore, an important feature to understand was whether the tapestry, as an interface, would allow the user to learn while interacting with this interactive piece. Moreover, it was also crucial to understand if we could use the tapestry artcraft to give life to a story regarding marine biodiversity issues.

Regarding these statements, we decided that evaluating several features of our project would be necessary. Some of the features we wanted to understand were the user experience with an interactive tapestry as an interface, the user knowledge before and after interacting with the interactive tapestry, the analysis of the understanding of the project, and, more concretely, the narrative and its theme. So, we wanted to evaluate our design approach in terms of the user experience, user knowledge, and understanding.

Artistic interventions require for a mixed-method evaluation [35, 74, 75]. So, to evaluate the interaction with our piece, we collected data using: 1) questionnaires, 2) observation allied with taking notes and the participants think-aloud while interacting, 3) video recording, 4) Semi-structured interviews with audio recording.

5.1 Pilot Study Protocol and Metrics

Participants were recruited using a convenience sampling [76] method. We conducted the pilot study at Centro Cultural e de Investigação do Funchal (CCIF) in a room used only for the pilot study. We asked the participants to interact with the piece individually and anonymised each participant's data by giving every participant an ID number. Questionnaires were developed with Google Forms to be analysed more efficiently, and we followed the same procedure for every participant. The procedure involved three central moments in which a researcher was always present. The protocol moments and metrics collected were the following:

1) Introduction: The researcher welcomed the participants, explained the overall goal of the evaluation, and handed out the consent form to the participants, which explained all the details. Then, the researcher asked the participants to answer a pre-experience questionnaire subdivided into two sections. The first section was a questionnaire to gather demographic data, such as age, gender and nationality. The second one contained ten questions about the ocean, where five asked general questions inspired by existing questionnaires [77, 78] and five others with questions they might learn from the interactive tapestry narrative. We used this questionnaire to collect data about participants' level of knowledge regarding biodiversity issues. These questions are available in C Appendix.

2) Prototype Interaction: Then, we asked the participants to interact with the interactive tapestry. We told the participants that the interactive piece must work without our help since all the instructions they might need were present in the audio tracks of the interactive tapestry. However, we would be there to help if they felt extreme difficulties. We also asked the participants to think aloud during the interaction [79], and we told each participant that we would observe them, take notes, and record a video. The participants were always aware of what was happening and conscious of our presence. This method aimed to gather data related to the user behaviour and understanding of what the narrative asked to do during the interaction with the interactive

tapestry. Here, we could also compare, analyse, understand, and evaluate the different types of touch used by participants.

3) Post Interaction: We asked the participants to complete a questionnaire subdivided into four sections. We gave this questionnaire immediately after the interaction so the participants could express their first impressions immediately. In the first section, we used the User Experience Questionnaire (UEQ) [80], which evaluates usability and user experience features. UEQ has six scales with 26 items. The six scales focus on attractiveness, perspicuity, efficiency, dependability, stimulation and novelty evaluation. In the second section, we used five adapted questions from the EgameFlow questionnaire [81], which evaluates in terms of interface flow and its usability, and three questions from the Transportation Scale [82], which evaluates the narrative flow and the user engagement through a general question and three topics related to cognition, emotion and imagination. Furthermore, in the final section, we used the same questions about the ocean we used before. Finally, we conducted a semi-structured interview in which we recorded audio. This interview aimed to understand better what the participant reflected after hearing the story and interacting with the tapestry. All these questions are available in D Appendix and E Appendix.

5.2 Data Analysis

After proceeding with the pilot study, it was time to prepare the collected data to be analysed. This phase was crucial to understanding if there was any lack of data or outlier values among what we collected.

As previously said, we collected qualitative data, such as our notes from observing the interaction with the interactive tapestry with correspondent videos and participant interviews with correspondent audio. In this phase, we prepared these data to facilitate the analyses.

From the interaction moment, we collected notes and videos. We placed all these written data in a Google Spreadsheet document, subdivided by participants and tasks each participant had to execute. We also tried to connect observation notes and videos to understand better what happened during the interaction. Moreover, we added some notes related to their behaviour, such as their facial and body expressions, our interpretation, and what they said while hearing their reactions to the narrative and tasks.

Then, we transcribed each interview to a Word document from the collected audio during the interviews, separating each interview by the participant number. To analyse this data, we did a thematic analysis. Here, we categorised the responses to find recurring themes and patterns to answer our research questions. For this categorisation, we used the tool Taguette [83], which allowed us to highlight sentences or words to tag them by different codes, helping us easier to extract the answers we were searching for.

Since we did every questionnaire using Google Forms, it was possible to transport the collected data to the Google Spreadsheet, which allowed us to see all the results together and divide by each question.

The UEQ already provides an organised Excel document with every calculation we needed to analyse the data collected for this part of the questionnaire, where we could analyse our results.

We have not used the complete questionnaires for the EgameFlow and the Transportation Scale, so we exported the collected data to an Excel document, where we analysed the data per question.

5.3 Results

We recruited 26 participants to test and evaluate this interactive experience, and this section presents the results obtained. We start with the quantitative data, with the demographic results, the questionnaires about the ocean results, before and after the experience, and then the results of the User Experience Questionnaire, the EGameFlow Questionnaire, and the Transportation Scale. Moreover, we will share the qualitative data results from the notes we took, videos from participant interactions, and the after-the-experience interviews.

5.3.1 Demographic Results

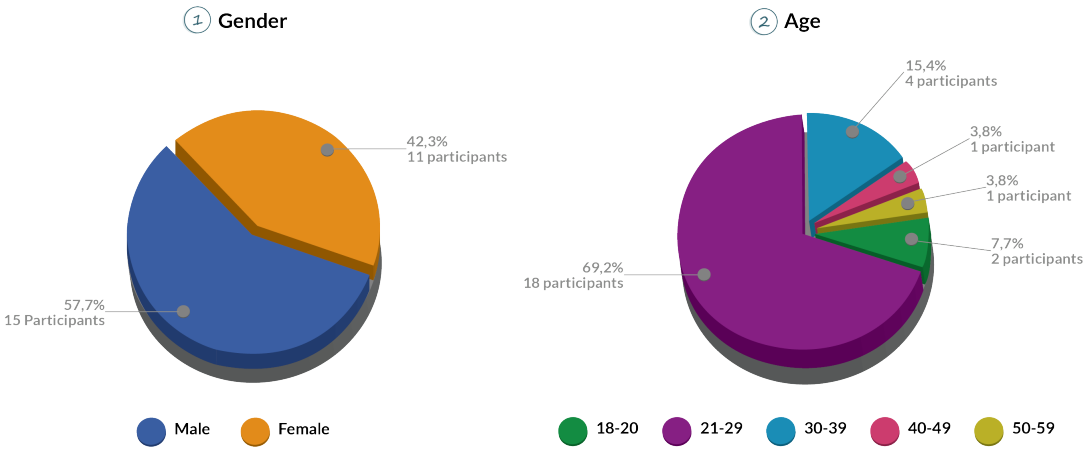

Fig. 40. Demographic Results: 1)Participants Age; 2)Participants Gender

The graphics in Fig 40 show the gender and age range of our participants, respectively. As we can see, the age ranged between 18 and 59. The age range with the most participants (18 participants) was from the participants who were 21 to 29 years old. Moreover, 15 of the participants were male, and 11 were female.

5.4 Quantitative Results

5.4.1 Questionnaire about the ocean – Results Before and After the Interaction with the Interactive Tapestry

The following table (see Fig.41) displays the results of our questionnaires about the ocean before and after the interaction with the interactive tapestry. We attributed 100 points as a total score for the questionnaire. Each question had the same amount of points (10 points). When the questions have more than one possible answer, we divided the total (10 points) equally per answer. We assumed that the total score in each questionnaire represents each participant's knowledge about the ocean. Our goal was to understand if the level of knowledge changes after interacting with the interactive piece.

Before interacting with the interactive piece, our participants had the results presented in the Fig.41, column 'Questionnaire 1 (Before)'. We can see that the evaluation values vary from 32,01 points to 98 points. The average level of knowledge in the questionnaire before the experience is 62,63 points.

Participants	Total Score of Questionnaire 1 (Before)	Total Score of Questionnaire 2 (After)	Difference between Questionnaires
P004	57,01	81,85	24,84
P005	66,18	69,34	3,16
P006	57,35	67,35	10
P007	83,17	82,51	-0,66
P008	55,52	74,84	19,32
P009	51,18	74,01	22,83
P010	48,18	76,86	28,68
P011	32,01	44,01	12
P012	80,68	91,01	10,33
P013	61,02	64,35	3,33
P014	61,02	77,18	16,16
P015	63,19	60,02	-3,17
P016	73,01	66,35	-6,66
P017	75,35	69,02	-6,33
P018	53,69	81,01	27,32
P019	36,01	54,86	18,85
P020	98	99	1
P021	86,02	73,52	-12,5
P022	39,51	70,68	31,17
P023	41,18	57,34	16,16
P024	66	69,68	3,68
P025	82,01	84,01	2
P026	60,01	83,68	23,67
P027	69,51	68,68	-0,83
P028	54,85	85,18	30,33
P029	74,18	79,69	5,51
Average knowledge level	62,53	73,31	**10,78**

Fig. 41. Questionnaires about the ocean results - Average level of knowledge

After interacting with the interactive piece, our participants had the results presented in the Fig.41, column 'Questionnaire 2 (After)'. We can see that the evaluation values vary from 44,01 points to 99 points. The average level of knowledge in the questionnaire after the experience is 73,31 points.

The column 'Difference Between Questionnaires' represents the difference between 'Questionnaire 1 (Before)' and 'Questionnaire 2 (After)' values of points per participant. Twenty participants increased their results between questionnaires. The highest positive difference in knowledge between questionnaires was 31,17 points, and the lowest was 1 point. However, there were six cases where the difference in the level of knowledge was reduced instead of growing, meaning that the levels are negative values for the growth of knowledge. Nevertheless, the average level of knowledge grew by 10,78 points.

5.4.2 User Experience Questionnaire (UEQ) Results

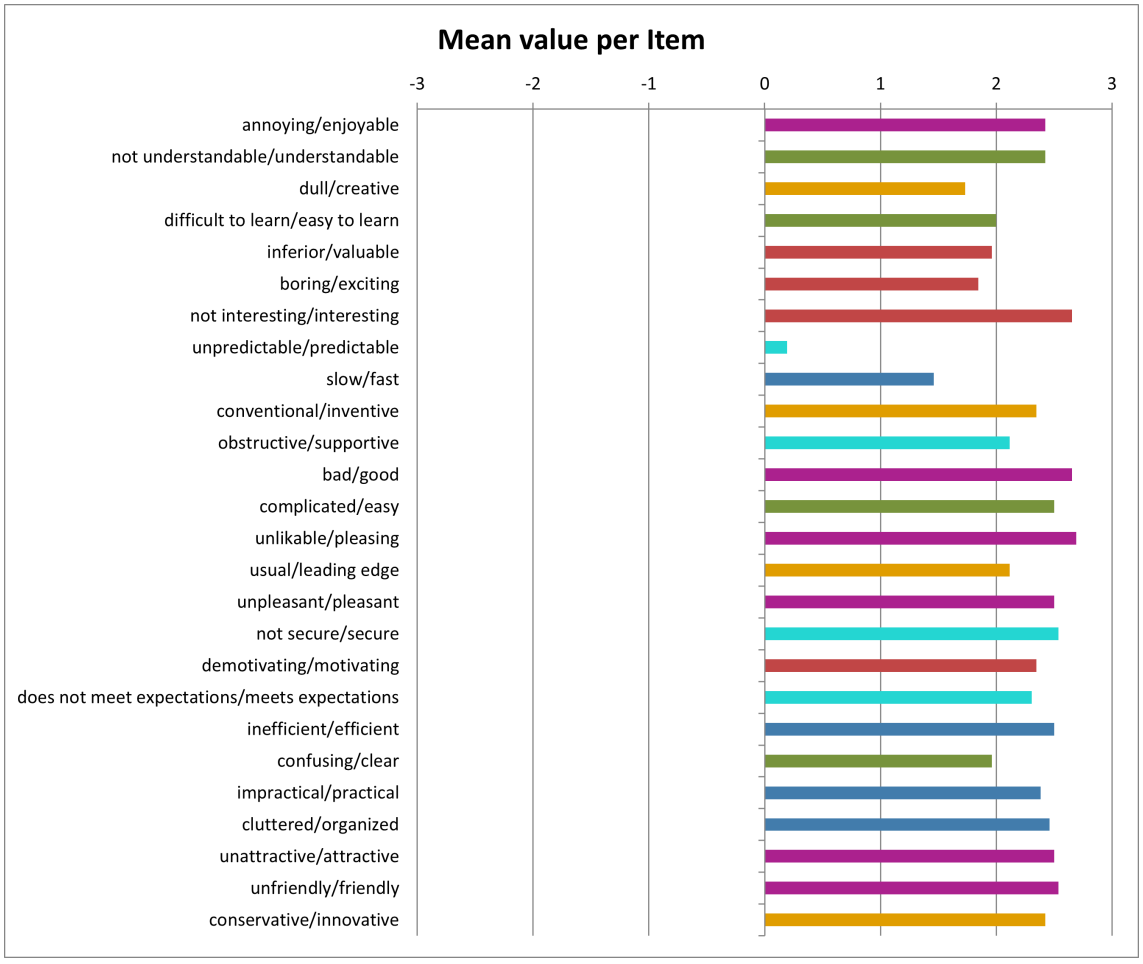

Fig. 42. UEQ Mean Value per Item Results

The User Experience Questionnaire evaluates the 26 items, inserted in six scales, between -3 and 3, with the first being "horribly bad" and the second "extremely good". This graphic represents the mean of the 26 participants' answers.

In Fig. 42, we can see which categories were better or worse. All the 26 items had positive results. However, some had lower results, especially the "unpredictable/predictable" parameter, in which the mean was close to 0, meaning it was almost neutral. Nineteen parameters had results above 2, and the other six had results between 1 and 2.

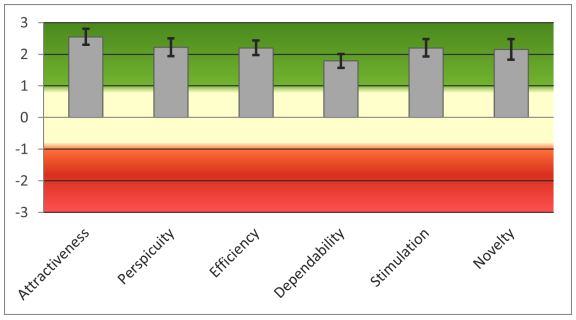

Fig. 43. UEQ Mean and Variance Results

In Fig. 44 we can understand that every scale has a positive mean since each bar is in the green area, above 0,8 –Attractiveness, Perspecuity, Efficiency, Stimulation and Novelty present results above 2. We can also see that the lowest bar relates to the Dependability scale, presenting results under 2. The dependability scale evaluates the items "unpredictable/predictable", "obstructive/supportive", "not secure/secure", and "do not meet expectations/meets expectations". Analysing both the above graphics, we understand that the item "unpredictable/predictable" is the item that most influences this scale. We can also see that the responses' variance is generally inferior to 1.

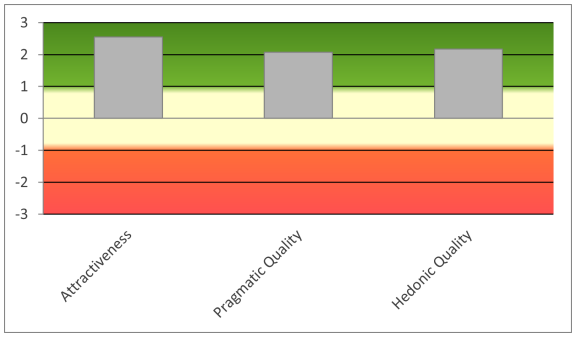

Fig. 44. UEQ Pragmatic and Hedonic Quality Results

UEQ also divides the scales through three other scales (see Fig. 44): the Attractiveness, with six items; the Pragmatic Quality, related to tasks quality, with three scales (Efficiency, Pespecuity and Dependability) with four items each; and the Hedonic Quality, related to non-tasks quality, with two scales (Stimulation and Novelty) with four items each. All these scales present positive results, above and close to 2.

5.4.3 EGameFlow

Since we have not used the total questionnaire for the EGameFlow, we analysed each question alone. We used five questions on this scale. On this scale, 0 corresponds to "Strongly Disagree", and 5 corresponds to "Strongly Agree", meaning 3 is neutral.

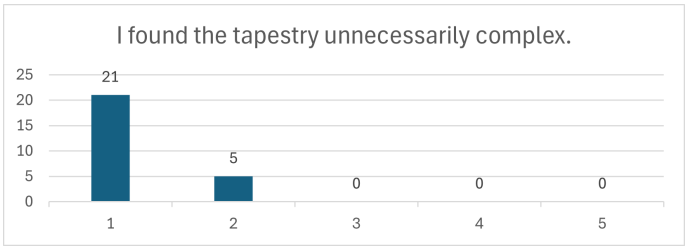

Fig. 45. Question 1 EGameFlow

On the first question (see Fig. 45), 21 participants answered that they strongly disagreed (1) with the statement, "I found the tapestry unnecessarily complex.". The other 5 participants disagreed (2). No one answered the other options.

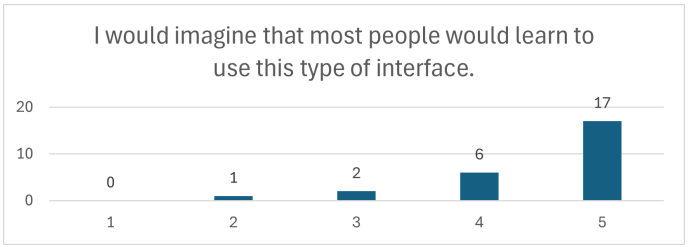

Fig. 46. Question 2 EGameFlow

On the second question (see Fig. 46), 17 participants answered that they strongly agreed (5) with the statement, "I would imagine that most people would learn to use this type of interface.". 6 participants answered that they agreed (4), 2 participants were answered neutral (3), and 1 participant disagreed (2). No one answered the other option.

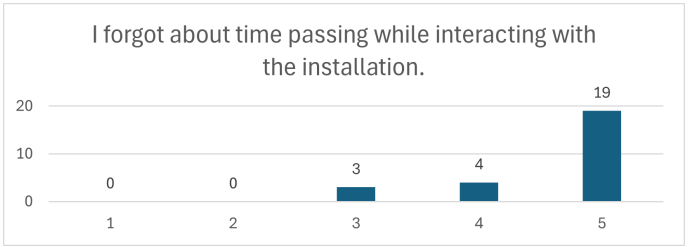

Fig. 47. Question 3 EGameFlow

On the third question (see Fig. 47), 19 participants answered that they strongly agreed (5) with the statement, "I forgot about time passing while interacting with the installation". 4 participants

answered that they agreed (4), and 3 participants answered neutral (3). No one answered the other options.

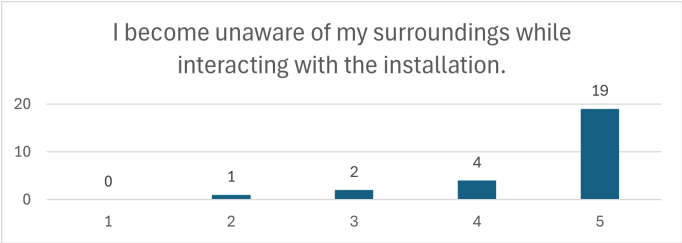

Fig. 48. Question 4 EGameFlow

On the fourth question (see Fig. 48), 19 participants answered that they strongly agreed (5) with the statement, "I become unaware of my surroundings while interacting with the installation.". 4 participants answered that they agreed (4), 2 participants were answered neutral (3) and 1 participant disagreed. No one answered the other option.

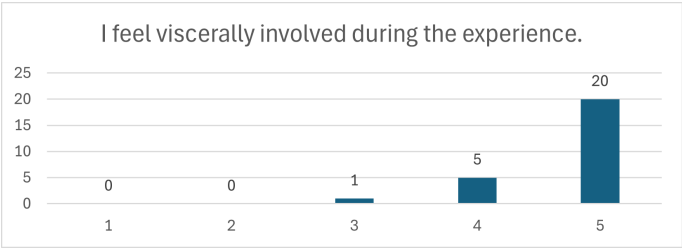

Fig. 49. Question 5 EGameFlow

On the fifth question (see Fig. 49), 20 participants answered that they strongly agreed (5) with the statement, "I feel viscerally involved during the experience". 5 participants agreed (4), and 1 participant was neutral (3). No one answered the other options.

5.4.4 Transportation Scale Results

Since we have not used the total questionnaire for the Transportation Scale, we analysed each question alone. On this scale, 0 corresponds to "Not at all", and 7 corresponds to "Very much", meaning 4 is neutral.

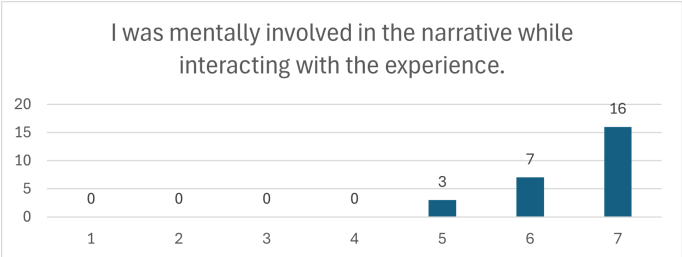

Fig. 50. Question 1 Transportation Scale

On the first question (see Fig. 50), 16 participants answered "Very much" (7) to the statement, "I was mentally involved in the narrative while interacting with the experience.". 7 participants answered 6, and 3 participants answered 5. No one answered the other options.

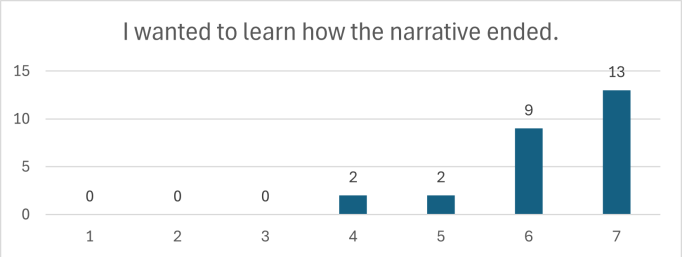

Fig. 51. Question 2 Transportation Scale

On the second question (see Fig. 51), 13 participants answered "Very much" (7) to the statement, "I wanted to learn how the narrative ended.". 9 participants answered 6, 2 participants answered 5, and 2 participants were neutral (4). No one answered the other options.

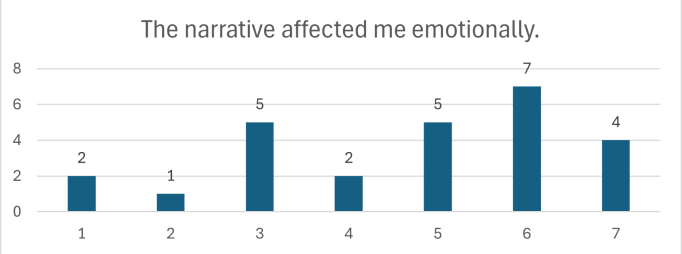

Fig. 52. Question 3 Transportation Scale

On the third question (see Fig. 52), 4 participants answered "Very much" (7) to the statement, "The narrative affected me emotionally.". 7 participants answered 6, 5 participants answered 5, 2 participants were neutral (4), 5 participants answered 3, 1 participant answered 2, and 2 participants answered, "Not at all" (1).

5.4.5 Interaction with the Interactive Tapestry Duration

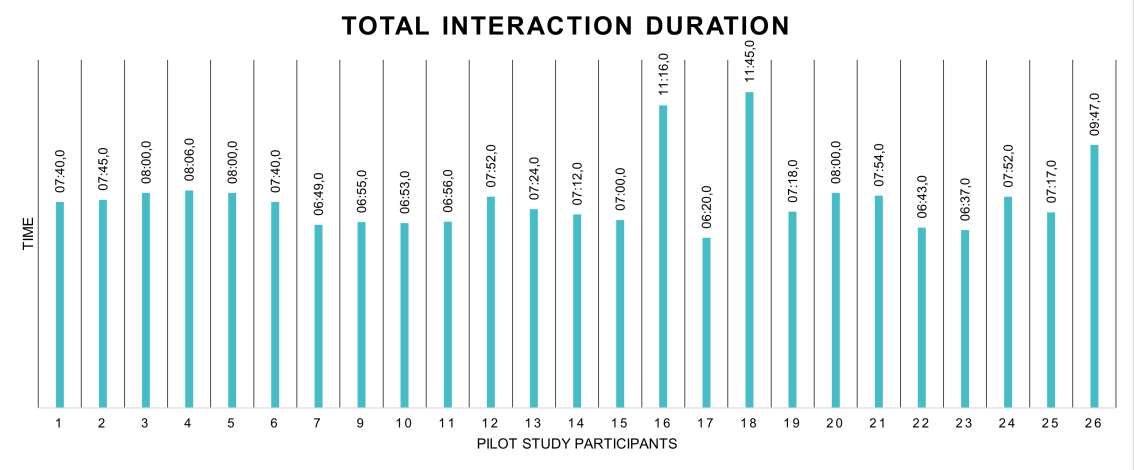

Fig. 53. Duration of the interaction with the interactive tapestry

One of the parameters we collected from the videos was the time spent interacting with the interactive tapestry (see Fig. 53). However, we could not collect video data from a participant because we had a problem with the camera, so we removed the participant from this chart to have a more coherent average result. The participants' average time was 7 minutes and 48 seconds. The minimum time was 6 minutes and 20 seconds, and the maximum was 11 minutes and 45 seconds.

5.5 Qualitative Results

5.5.1 Interaction Areas Results

We analysed some relevant interaction parameters by collecting notes from the observation and video. Here, we give an overview of what we analysed from the first to the final interaction. During the participants' interactions, we observed the different types of touches and facial, body and oral expressions, influencing our perception of how we analysed their posture while interacting with the tapestry. We also tried to understand until what point the interactive tapestry survives without the author's help. Another parameter we analysed was the total duration of the experience.

Interaction 1 - Initial Sensor: All the participants executed this task. Nineteen participants out of twenty-six executed the first interaction without problems. Three participants observed the tapestry with much attention before interacting with the interactive piece, which made them execute the task without any problem. Five participants felt confused about starting the experience because they had not read the initial message on the plinth. Three of these participants started to use an explorative touch to find where the sensor was on the two pieces of tapestry. Nine participants started by asking questions with doubts, but quickly, they understood we would not give them any answers, so they understood what to do. We observed several types of touch: eleven participants had a standard touch, one used one finger to touch, six touched with too much strength, and two kept touching the first sensor until the end of the first audio. We had to give some indications to four participants so they could find the first sensor without telling them where it was.

Interaction 2 - Place the Whale on the left side tapestry: In general, all the participants were able to place the whale. Twenty participants placed the whale without any problem. Five participants were confused about where to put the whale, and three of them needed our indications to understand, such as to step back to see all the pieces. One of these participants started by placing the whale on the right tapestry because she had been looking at the whale silhouette on the right side since the beginning of the pilot study. Two participants used too much strength while placing the whale as if they needed to fix it. One participant explored the tapestry texture while hearing the audio. A participant had a problem with the magnets not holding the whale, but he quickly repositioned it.

Interaction 3 - Touch the sound waves came from the whale: Everyone completed this interaction. However, the interaction and the sensor seemed to have several problems. We noticed that thirteen participants could not put the sensor working at the first touch, sometimes because of the touch type and sometimes because they had not waited for the end of the audio. Eighteen participants could solve the touch with not much problem. If the sensor was not working, they tried again until they received audio feedback. A participant received our indications to continue. One participant observed the whole tapestry. Five participants demonstrated to be confused or in doubt. A participant demonstrated enthusiasm for the narrative. Three participants explored the touch while hearing or waiting for the audio to play. Two participants used a finger to touch, which made the sensor detection difficult. Two participants used more strength to activate the sensor. Another participant first touched the warp thread before noticing the sound waves. Moreover, another first touched the ocean.

Interaction 4 - Place the clownfish on the left tapestry: Every participant was able to execute this interaction without any help. Five participants had minor problems where the sensor did not work. One participant said it was because he touched too soon; the other four did not say anything but repositioned the clownfish, and it resulted. Two participants laughed at the narrative. Another participant said the clownfish character was talking too fast. Moreover, we noticed that one participant observed the whole tapestry after interacting. Three participants felt confused.

Interaction 5 - Touch the anemone: Everyone completed the interaction without any help. We noticed that seven participants felt confused or in doubt. Four participants said they understood what to do because of the orange tentacles description. Two participants demonstrated some fear of touching the wrong sensor. Three participants touched other tapestry elements before touching the anemone. A participant grabbed the anemone's tentacles and pulled it while analysing its texture. Another participant said the sound of the anemones sounded like a bonfire. A participant said that the clownfish spoke too fast. Two participants used an explorative touch while interacting with the anemone. One participant could not display the sound with the first touch, but he solved touching again.

Interaction 6 - Touch the green ocean invading the blue ocean on the left tapestry: All the participants found the sensor. Twenty-three participants did not need help. Three needed some indications to understand. At least nine participants expressed confusion and doubt before finding the correct sensor. A participant placed the characters on the right tapestry before understanding where to touch the green zone. Six participants touched other elements before touching the correct green zone. We noticed that eleven participants used more observation to execute this task. At least three participants demonstrated to be having fun with the narrative.

Interaction 7 - Place the clownfish on the right tapestry: Every participant executed the interaction without help. Six participants demonstrated some confusion. Five placed the whale first, and the other simultaneously placed both characters on the right tapestry. Two participants observed the tapestry with more attention. In the previous interaction, the participant who first placed the characters on the right tapestry understood that he should touch the clownfish to execute this task. At least one participant demonstrated to be having fun with the narrative.

Interaction 8 - Place the whale on the right tapestry: All the participants could execute the interaction without help. Two participants demonstrated some confusion. One of them, who already had the whale on the right tapestry, brought it back to the left but soon understood that he should put it back on the right tapestry (confusion because of the name "Echo"). Two other participants, who already had the whale on the right tapestry, understood they needed to touch it again. Four participants demonstrated to be preoccupied, scared or restless because of the narrative events. Six participants made a reflection while hearing the narrative. A participant used too much strength to put the whale on the tapestry. Two participants needed to touch the whale again because they had not waited for the end of the audio. One participant laughed at the narrative. Another participant stepped back. We assumed it was because of the narrative impact.

Interaction 9 - Touch the ships to stop the noise: Everyone completed this interaction without help. Eight participants expressed their emotions with facial and oral expressions related to the human attitude. Two participants seemed restless. Two others laughed. Two participants shared some reflections about the theme. A participant felt confused because he touched the ship to stop the noise, but since he was not hearing anything, he stopped the noise. After some seconds, he tried to touch the ship again and heard the audio. Seven participants had to repeat the touch because the first one was too soon. Two participants said they should wait for the audio to end before touching it. Moreover, two participants seemed to be feeling the ships' texture.

Interaction 10 - Place the whale and the clownfish on the left tapestry again: Everyone completed this task, but not everyone could do it without an indication. Twenty-one participants could execute the task without help. Six participants needed to reposition the characters to hear the audio. Eight participants felt confused. We had to give indications to five participants. We noticed two different ways of bringing both characters to the left tapestry: sixteen participants brought the characters separately; the other ten brought the characters simultaneously, sometimes placing them simultaneously and sometimes separately. We needed to give some indications to five participants so they could reposition the characters and hear the audio file. One participant expressed a reflection about the anemone and sound.

Interaction 11 - Place the whale and the clownfish on the plinth: All the participants concluded the last interaction without help. Two participants had to reposition the characters to hear the last audio. When finishing the experience, one participant left the headphones in a different place, above the beginning written message. One participant was still observing the tapestry when hearing the last audio.

5.5.2 Semi-structured Interview Results

The following overview displays the analysis of the interviews we did. We grouped our data around the main topics we discussed with the participants. However, not every participant discussed every topic.

Interactive Tapestry Concept: We asked the participants about their understanding of the concept of this interactive tapestry. Sixteen participants told us that it was about noise pollution. Five participants said it was about marine pollution in general. Sixteen participants referred to the impact of human actions on the marine environment, especially on marine animals. Two participants understood the concept referring to the two different ocean phases. Two other participants told us about the knowledge they acquired about marine species. Moreover, two other participants said the tapestry brings awareness to the theme.

Notorious Differences between left and right tapestries: We asked the participants if they noticed and how they found the differences between tapestries and worlds. Fifteen participants told us about the colours, understanding that the blue ocean and the colour vivid coral reefs represented a clean and healthy ocean and that the greenish colours and unsaturated, dead colours of the coral reefs represented a polluted and unhealthy ocean. Only one person noticed that the ships had a different material, but no one noticed the texture difference. Seven participants noticed differences related to the concept, where they emphasised the presence or absence of humans and their actions. Three participants said they noticed this difference because of the narrative. Seven participants noticed the difference because of the present elements in the tapestry, focusing their attention on the presence of the ships and the absence of the anemone on the unhealthy side of the ocean. Four participants referred to sensations where they felt calm on the healthy side of the ocean and disturbed on the unhealthy side. Furthermore, eight participants noticed the difference in sound between both tapestries, emphasising the disturbing sound of the ships on the unhealthy side and the calm ocean on the healthy side.

The connection between the Different Media (Technology, Tapestry technique, Narrative): We asked if the participants thought the technology, the tapestry technique, and the Narrative were well-connected and cohesive. Twenty-two participants said that every element was well connected. Three participants said it was a cohesive and unified piece. Another participant said it was well articulated that each element completes the others. One participant expressed that he was afraid of touching a different sensor, different from the following touch, and afraid of displaying the wrong sound. He said it was great to have a predefined order to display the sounds and said it was great to have that orientation. One other participant said it was consistent enough. Another said it was better than he expected. One participant said the interactive piece was easy to perceive, and another said it was well-connected with creativity. A participant also said it was interesting how we used tapestry with sound and its tactility power.

Power of Decision: We asked some of our participants if they felt they had any power of decision. Two participants said they felt little power. One said he felt power when stopping the ships' noises. Two others felt the story was linear, so they could not do much. Three participants felt the power of decision while touching the tapestry and felt they were essential to the narrative since their actions had an effect, so they were a conduit to something in the narrative. Another participant said he felt he was accompanying the characters during the journey. A participant said she did not feel the power of decision but the power of helping the characters. Two participants said they felt no power of decision since the narrative tasks conducted them.

Duration: We asked some of our participants what they thought about the duration of the experience. Four participants told us the duration was enough. One said it was enough not to get annoyed, and another said it was enough because long experiences might end up tiring. One participant said that the experience was too fast in some moments due to the quick clownfish

sentences. Five participants said the experience was too short, and one said he would do at least one more interaction because it ended quickly. Two participants did not notice the duration of the experience, saying it was because the experience was well-developed. One participant understood that the interaction level limited the duration. However, if it was for a museum context, it was enough.

Emotions, Feelings and Reactions: We asked our participants if they felt any emotions, feelings or reactions. We received several different answers, and only three people said they felt no emotions. One said it was because of the study constraints. Three participants felt happiness, joy and pleasure. Two participants felt enthusiasm. Seven participants felt worried about the narrative events. Ten participants empathised with the characters, and eight felt more empathy for the whale Ava. A participant also said she felt compassion for the whale. The experience also transmitted sadness to three participants, anxiety and stress to one participant and relief to another participant. Another participant felt angry. Five participants said they felt amused with the voice acting, especially with the clownfish voice acting. A participant also said she felt calm and abstracted from the surroundings. One participant compared herself to the characters. Seven participants reflected on the theme and human actions. Another participant said she felt like she was in a children's story. Four participants said they felt an immersion sensation during the experience, and a participant explained it was because of all the elements involved in the experience, from sound to touch and grabbing the characters to place them on the tapestry.

Target Audience: Two participants referred children, adults and older people to interact with the interactive tapestry. A participant said that anyone, children or adults, would pedagogically benefit from this type of project. The other participant said that this would be perfect for children.

Changes Suggestions: We asked the participants if they would make any changes to the tapestry, and we received several suggestions about the different components of the tapestry. Three participants said we could give more precise instructions, especially if the audience were elderly or children. A participant also said that would make the first sensor more visible with the instruction to touch it more visible as well, and another said we should explain how long they should wait until the subsequent touch would be good. Eight participants made suggestions about the audio: Two of them told us we should increase the ship noise audio so the user feels even more disturbed; four participants said we should reduce the audio velocity when the clownfish speaks so they could understand better what is said; a participant said it would be nice to always keep the ocean track sound as background, without stopping; and other participant said we should make the sound even more dynamic, increasing the voices when the characters speak, and make the background sound lower, and vice-versa. Concerning the visual aspect, two participants suggested four changes: one participant said we should make the unhealthy side of the ocean more realistic and scary as they do in the animated movies; another participant said we should make the ships more recognizable, add visual ship sound waves as we did with the whale, and that we should eliminate or reduce the space between the two tapestry pieces. Two participants suggested changes to the narrative. One said we should add a more surprising event, like finding a lost friend on the other side they meet unexpectedly.

Moreover, the other said we should add more ocean facts for the user to learn. Concerning the characters, a participant said he misunderstood the name of the clownfish with the sound waves because "Echo" sounded like something related to sound. A participant said that adding light to the tapestry would be nice. Furthermore, two other participants said it would be nice to have

lights, sound and vibration as feedback when the user touches the tapestry so he knows the sensor detected his touch. A participant also said we should add more media components. Concerning the user experience, five participants would add more interaction to the tapestry. Two of them suggested that other tapestry elements could also have interactions. Four participants explained that we should give these interactions as “Easter eggs”, surprising the user with extra sounds. A participant suggested that we make the green zone more visible, maybe directly connecting this zone to the unhealthy side of the ocean. Two participants also said giving the user more autonomy and liberty would be great. A participant also said we should have a plan for when the user leaves in the middle of the experience. Another participant told us that she felt overwhelmed with all the information, and if it was possible to hear the narrative again, it might be easier to have a better understanding and learn better. She also said it might not be possible in a pilot study, but it could be possible if the art piece were in a museum.

6 Discussion

The evaluation of this thesis project pretended to answer our research questions presented at the beginning of this dissertation.

Discussing our work starts by remembering and reflecting on our primary research goals. Then, we address each of our research questions and, towards the end, we reflect upon the limitations and future work related to our research.

6.1 Research Goals

Our first research goal was "RG1: The creation of an interactive tapestry that tells a story to raise awareness towards marine noise pollution." and our second research goal was: "RG2: Assess the interactive tapestry impact on the audience in terms of audience engagement and usability with the final piece and the impact interacting with the piece will bring.".

Regarding RG1 we consider that our interactive tapestry presented positive results since when we asked about their interpretation of the tapestry concept during the pilot study, most participants reflected on the noise pollution theme, emphasising the impact human intervention causes on the marine environment, especially on marine animals, and some of them also said the experience fosters awareness.

Regarding RG2, we consider that, in terms of audience engagement, we had positive results since in the eGameFlow, and Transportation Scale questionnaires, the majority of the participants answered that they felt viscerally involved during the experience, forgot about time passing while interacting with the experience, and became unaware of their surroundings. Moreover, most participants wanted to learn how the narrative ended and were mentally involved during the experience. During the interviews, some participants also said they felt immersed because of all the tapestry components. Others completely forgot about the time and would do more interactions if needed, which might be a limitation of our technology because the BCTB only allows twelve soundtracks. Regarding usability, the UEQ demonstrated excellent results. However, from our observation notes and interviews, we noticed minor usability problems concerning the sensor areas or the audio instructions that were not clear enough, where we see space for improvement. Regarding the impact of interacting with the interactive tapestry, some participants felt they were emotionally affected and expressed their feelings through facial, body and oral expressions during the interaction moment. Moreover, during the interview, some participants said they felt emotions like empathy, compassion, sadness, anxiety, stress, angryness. Some others also reflected on human intervention in the oceans, demonstrating they understood the impact on the marine environment.

6.2 RQ1: How can we design an interactive tapestry that serves as a TUI for a story?

Due to the story potential of tapestries, we chose a theme and message for our tapestry, making it essential to consider how this medium can effectively communicate our message. We decided to weave in a story regarding marine noise pollution, where the characters tell knowledgeable content in a conversation directly with the user, involving him in the narrative.

To promote user interaction with our interactive tapestry, we designed this project thinking of the user experience from the beginning to the end. We developed our design thinking of the

narrative construction and how we could display this visually in the tapestry, giving attention to the user interaction details. We had to think of how the user would interact with the characters and how these characters accompanied the story, involving the user's interaction and how he would understand where and when to touch. So, we had to sketch and think about all the tapestry visuals according to this logic and the audio instructions with understandable clues. We gave special attention to the visual affordances so the user could understand his role and what he had to do. For example, the volume of our diegetic characters made the user understand he has to grab the characters to place on the tapestry, and the visual affordances created for the space where the user needed to place them. We observed this parameter while the participants interacted with the tapestry in our pilot study to test our approach. We saw that almost all the participants quickly understood what to do when the tapestry asked to place the whale. Moreover, we noticed that even the other participants to whom we gave some small instructions, without saying where it was, concluded where it was.

We had encouraging results on the UEQ, and we can also say that, in general, the participants gradually learned how to use this interface since when the interaction was similar to the previous ones, they were already familiar with it and executed it without help. We believe this because most participants tried to readjust the characters or repeat the touch when the interface was not answering immediately. Another example is when some participants understood they had to wait for the audio to finish to execute the following interaction. However, we understood that we could improve the audio by reducing the characters' speech velocity or giving better instructions and details, as we did with the anemone, referring to a characteristic it has, the orange tentacles. We noticed that some participants found it challenging to find the piece of green ocean invading the blue ocean, and maybe it was not just because of the character's speech velocity. We can also improve the visual so that the users can understand where it is.

We knew that several users would interact differently. However, we could not predict all the users' types of interaction. For example, like a screen device, some participants touched the tapestry with one finger. Our sound waves were the perfect example of a sensor that did not react to this touch immediately. The results demonstrate that some users repeated the touch more than once in this interaction. These types of interaction also influenced the total time they spent interacting with the tapestry, allied to other factors, such as if they understood the following action, had to think for more time, or decided to explore the tapestry textures more.

6.3 RQ2: How can we integrate narrative elements in an interactive tapestry to raise awareness on biodiversity issues?

We could only answer this question by evaluating the audience's interaction and the consequent message that they might have retained. We found that a combined method was best for evaluating the interactive tapestry. Aasbakken [84] refers to several HCI evaluation methods for interactive art installations, such as observation, interviews, questionnaires, data recording, input logging and combining methods. Hence, to evaluate if our tapestry had the potential to deliver this message on marine noise pollution, we asked the participants to answer a questionnaire about ocean and marine noise pollution before and after the experience. In general, most participants improved their final score in the second questionnaire, which makes us believe that our tapestry positively affected the learnability domain.

We followed a traditional structure to design our narrative, which helped to divide the different events through the interactions. In our narrative, we introduced the characters and presented the environment where they live, the not polluted ocean, with everyday sounds. The results showed that it transmitted a calm sensation to some participants. After this, we start presenting the other side of the ocean with a piece of green starting to invade the blue ocean, instigating the characters' curiosity. The characters ask the user to place them on the other side, where the user puts the characters in danger. Then, we introduced the other side of the ocean, which is a polluted ocean and where the sound is disturbing. As we saw in the results, several users reported feeling negatively related sensations, such as restlessness and anger. They also felt sadness, empathy and compassion, understanding the whale and clownfish's pain. Then, we give the user (as a human) the ability to stop disturbing noises from the ships and help the characters, who are still disoriented, to return home. During the interaction, we also observed some participants reflecting on what they heard, repeating facts the characters explained and observing what they did not know, such as the whale and the anemone sounds, and how disturbing the anthropogenic intervention is.

6.4 RQ3: Can conductive technology be effectively integrated with traditional tapestry techniques to enhance the synergy with multimedia content?

We used the Bare Conductive Touch Board technology to support our weaving tapestry, allowing us to have several capacitive sensors that display audio feedback when touched, as used in several projects we found [10, 16, 33, 36, 37]. The seamless integration within the tapestry weaving was a challenging task. We explored several initial experiences to understand which materials worked better with textiles. Furthermore, we understood and predicted how we would implement it in the final prototype.

Preparing our weaving loom structure for the final prototype was a challenge. It required a logical strategy to maintain its strength and format to add the warp threads, where the nails must hold the thread in tension during the weaving execution. Another difficult task was to untangle all the collected wool from the community and to wind the IVBAM wool, for which we had to create an improvised mechanism to make the process quicker and easier. So then, we could find a new challenge to increase the sketch and arrange a new solution again. With all the preparation phases ready, we could finally start giving life to our design and exploring a known technique (weaving) while discovering how to implement several conductive materials. We also learned new techniques that took us more time to develop during the process. In conclusion, we integrated conductive threads and fibres with the wool to create the sensor areas, where we developed a very iterative process, always discovering new solutions.

We believe the union of the weaving tapestry technique with the technology and the narrative formed a tangible interface for storytelling with potential. During the interview, our pilot study participants told us that the experience resulted well and that all the components formed a cohesive and unified product. Some of them also said that it worked better than they expected. The results also demonstrate that it was a creative and original solution, which is not a complex experience and is not difficult to learn, as shown in our results.

6.5 Limitations and Future Work

We prepared the experience for a study context and planned it from the beginning to the end of a user experience. Then, the experience restarts, and it is ready for another user. However, something

we have not implemented yet is when a user might abandon the experience in the middle of it, in a real-life context, for example, in a museum. It might happen that our characters were still in the tapestry. We can solve this by asking the following user to replace Ava and Echo characters on the plinth to start the experience. However, we might need to add more visual indications, such as the characters' names close to the correspondent silhouette and a timer displaying audio when the following user asks to replace the characters on the plinth.

The interactive tapestry is ephemeral. Because the tapestry materials are wool and will be in contact with the user's touches, it will cause some damage with time and use. Due to the frequency of touch, we assume that the most damaged places will be in the interaction areas and elements. The solution to this problem might be to replace the materials after some time. In this case, we must ask ourselves if we should remove the tapestry from its loom structure, which will make it lose its warp tension. However, it is always possible to replace the materials even though the warp is without tension.

Soon, we will plan an exhibition for this embodied interface for storytelling. So, the existing interactive tapestry will require some improvements.

There is always space for improvement, and we noticed some features we can improve in our interactive tapestry. As we noticed with the pilot study, we must prepare our experience for a real context.

In the following phase, we will improve the sensor areas of the weaving tapestry, such as the sound waves, where we can increase the sensor with more conductive materials, and the audio tracks, where we can reduce the speech velocity and adjust the wording of the instructions.

Another future improvement is that we might explore a new avenue to expand this experience into the interactive narrative potential field, where we would add different possible endings depending on the user interactions, giving more autonomy to the user during the experience.

We noticed that, in general, the users assumed that they did not take advantage of the tapestry textures. For this reason, we might add a sentence to the initial narrator's speech, allowing the user to explore the touch and feel without fear.

We will also prepare a solution for the hypothesis of having a user who abandons the experience in the middle. Placing the names close to the whale and clownfish silhouette might be a good solution. Therefore, we would also set a timer after not interacting with the tapestry, where when another user comes to the experience, touches the first sensor, and hears a message that asks to replace the characters on the plinth to start the experience.

This way, we think we will have an embodied interface prepared for a bigger audience.

7 Conclusion

This thesis presents an innovative approach to the design process, execution, and evaluation of an interactive tapestry. This tapestry works as a TUI to an interactive story that fosters awareness of pressing anthropogenic issues with a particular focus on marine noise pollution. When we started this design process, our primary goal was to revive the weaving tapestry technique's inherent storytelling capabilities and tactile features, which we achieved by integrating capacitive sensors (such as conductive thread and fibre) connected to a microcontroller, the Bare Conductive Touch Board. We believe that utilizing this specific technology, which prioritizes conveying sound feedback through tactile sensations, significantly enriched the overall sensory experience since it inspired us to leverage more on a narrative about marine noise pollution, created to engage the audience, giving them a specific role as conductors of the continuity of the experience.

Through our research efforts, we contributed to creating an interactive artefact in response to research questions. We documented the design process, from the conceptual message we wanted to share with the audience to its visual aspect, materials, techniques, and colours to the narrative and the user role within the experience. Then, we executed all the tapestry, from choosing and acquiring wool and weaving loom creation to developing and implementing the conductive materials, recording audio, and testing. We believe that the documented design process constitutes a valuable contribution, offering numerous insights into integrating traditional tapestry techniques with innovative technology, all while prioritizing a narrative-driven experience.

Additionally, we further enrich the work of interactive storytelling Tangible User Interfaces (TUIs) by conducting user evaluations, deriving consequential insights, and offering proof of the potential of this medium to deliver a story that can impact the audience.

We aspire for our research efforts and this document to serve as sources of inspiration and guidance for future designers and artists who recognize the potential of tapestry as a Tangible User Interface (TUI) for Interactive Storytelling. However, we also acknowledge that we have only begun to uncover the vast potential of this medium, and we encourage exploration beyond the boundaries we've touched above.

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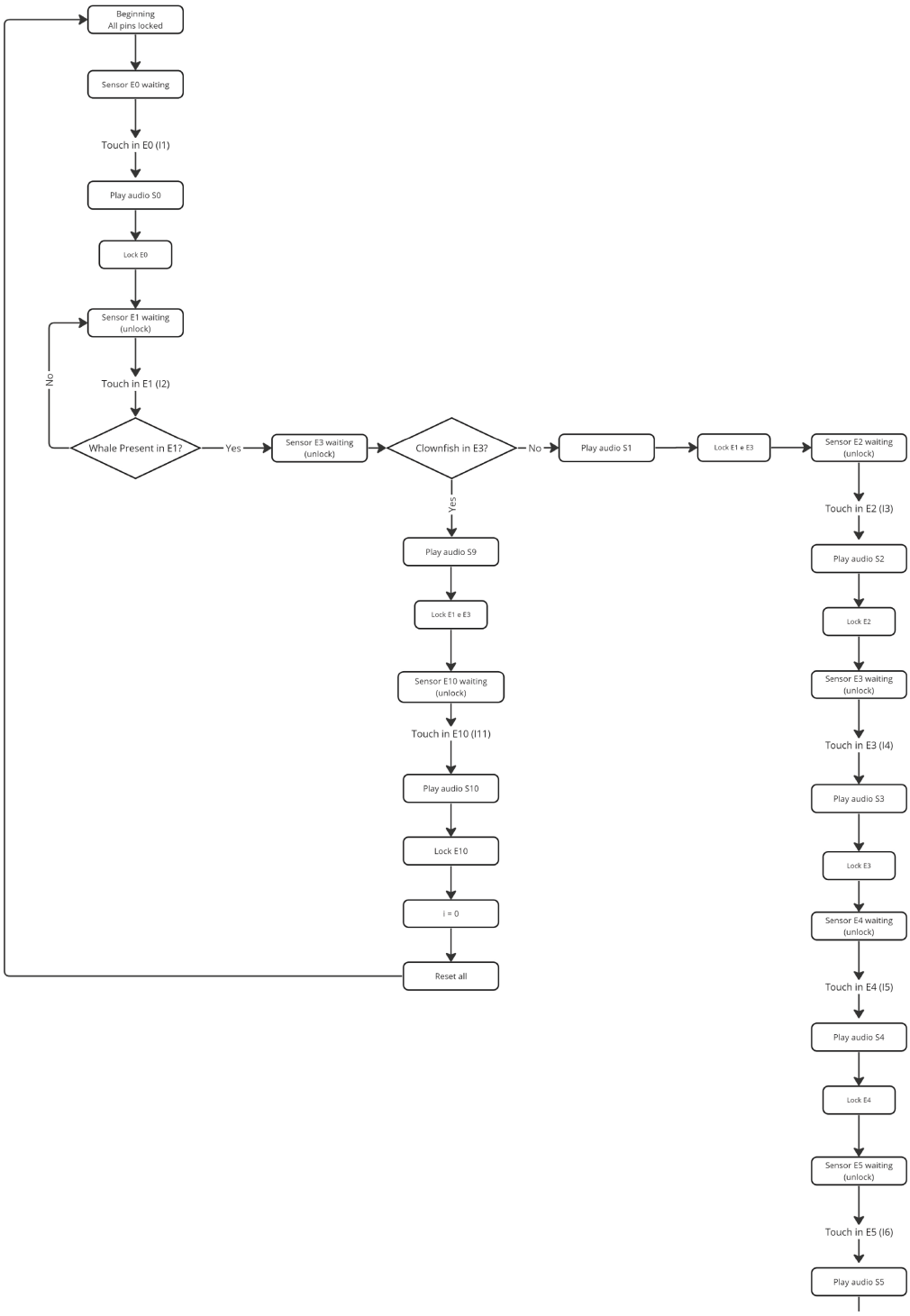
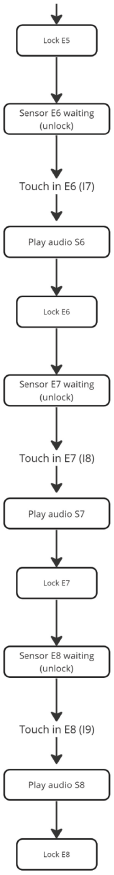
A Appendix

V.2 - Detect the whale and the clownfish presence




Lock E5
Sensor E6 waiting (unlock)
Touch in E6 (I7)
Play audio S6
Lock E6
Sensor E7 waiting (unlock)
Touch in E7 (I8)
Play audio S7
Lock E7
Sensor E8 waiting (unlock)
Touch in E8 (I9)
Play audio S8
Lock E8

B Appendix

Guião da Experiência 2 (cerca de 6:00 min)

Quantidade de utilizadores em simultâneo: 1

Intervenientes na narrativa:

-Narrador;

-Baleia – Bastante amigável, um pouco medrosa mas muito curiosa; ainda é pequena, mas já anda na escola e ao longo do tempo tem aprendido a navegar pelo oceano (nem que seja apenas de casa à escola e da escola a casa);

-Peixe-palhaço – Bastante amigável, muito aventureiro e muito curioso; Também é pequeno e tem a mesma idade que a baleia;

-Humano 1;

-Humano 2.

Experiência:

O utilizador chega ao pé da peça e encontra um pelinto com uns auscultadores que deve colocar nos ouvidos para dar início à experiência.

Interação 1 - Sensor E0

Encontra a mensagem que diz "Coloque os auscultadores e depois toque aqui para começar" no primeiro sensor. Ao clicar neste sensor, o utilizador ouvirá uma pequena introdução, a explicar os passos seguintes a serem executados.

Audio S0

- (narrador) Bem vindo a esta experiência interativa. A partir deste momento vai estar imerso nos ecossistemas marinhos. Para interagir com esta peça, deverá tocar nos vários elementos da tapeçaria. Aconselha-se a que siga os passos sugeridos.

Para dar início à experiencia, coloque a baleia no espaço correspondente na tapeçaria da esquerda.

Interação 2 - Sensor E1

(o user coloca a baleia na tapeçaria e um sensor será ativado com um novo áudio)

Audio S1 – (voz da baleia) - Olá! Eu sou uma baleia ainda muito pequena! Sei que ainda não nos conhecemos, no entanto quero que saibas um pouco mais sobre mim e sobre a minha espécie. Somos dos maiores animais que existem nos oceanos, e como connosco tudo é em grande, até o som que produzimos se propaga por grandes distâncias.

Toca nas ondas sonoras à minha volta para ouvires como comunicamos!

Interação 3 - Sensor E2

Audio S2

- (reprodução de sons de baleias, cerca de 10 seg ou menos)

(voz da baleia) - O som que emitimos serve para várias coisas. Serve para orientar-me, procurar comida mais facilmente, e às vezes, até fugir do perigo. Mas a maioria das vezes é só mesmo para chamar a minha mãe...

[- som da baleia –]

Ah sim! Esta sou eu a chamar pelo meu amigo peixe palhaço, ele também orienta-se pelo som que faço.

Hmm, estás a ver o meu amigo peixe palhaço? Coloca-o aqui, junto a mim.

Interação 4 - Sensor E3

(o user coloca o peixe-palhaço na tapeçaria e um sensor será ativado com um novo áudio)

Áudio S3

- (voz do peixe-palhaço) - Ah XXXX ainda bem que me chamaste, estava distraído! Realmente já está na hora de irmos para casa... Não convém chegarmos tarde, ainda por cima agora que os nossos pais já confiam nas nossas capacidades de orientação!

Oh! Olá! Nao tinha reparado que estavas acompanhada, XXXX! Eu sou o YYYY e sou um peixe-palhaço. Desde pequenino que ando a aprender a orientar-me pelo som, principalmente o da minha casa, nas anémonas. Aquela ali que tem uns tentáculos laranja claros... Toca nela para conheceres o som.

Interação 5 - Sensor E4

Áudio S4

- (o user toca na anémona e reproduz o som da mesma por cerca de 6 seg.)

(voz do peixe-palhaço) - As anémonas são seres vivos marinhos que protegem a minha espécie frequentemente de ser atacada. Em troca levamos-lhe comida e por isso é que nos deixa habitar lá. Não costumamos distanciar-nos muito das anémonas, e conseguimos encontrá-las através deste som (reprodução do som)

Agora que já conheces mais um pouco deste ecossistema, que tal continuares a explorar o oceano, toca ali naquela zona que está a ficar esverdeada, mais perto da tapeçaria da direita!

Interação 6 - Sensor E5

Áudio S5

- (voz do peixe-palhaço) Olha! O que foi isto? Vamos até lá investigar?

(voz da baleia) Mas... Os nossos pais dizem-nos sempre para não irmos para aquele lado do oceano! Sabes bem que é perigoso...

(voz do peixe-palhaço) Eu sei, eu sei... mas se nos aproximarmos só um bocadinho e regressarmos logo de seguida os pais não vão saber de nada... Tenho mesmo muita curiosidade em ver o que lá tem!

(voz da baleia) Pronto... Vamos lá espreitar, mas voltamos rápido!

(voz do peixe-palhaço) Bora lá! Humano, coloca-me no lugar correspondente na tapeçaria da direita.

Interação 7 - Sensor E6

Áudio S6

– (voz do peixe) Vá, não tenhas medo... despacha-te...

(voz da baleia) Sim já vou ... mas preciso de uma mãozinha... Humano, coloca-me junto à YYYY....

Interação 8 – Sensor E7

Áudio S7- (voz da baleia) Hum, este sitio tem uns ruídos um pouco diferentes da nossa casa... Não sei se gosto disto....

(voz do peixe-palhaço) Anda lá, vamos avançar só mais um pouco, está ali qualquer coisa a flutuar.

(Barulho do motor do barco a se aproximar, cerca de 8 seg.)

(voz do peixe-palhaço) Aii... não, não, não... Este barulho está a ficar muito forte! Vamos voltar para casa! (pausa por alguns segundos) Acho que já não sei como voltar... Ajudas-me?

(voz da baleia) Eu até ajudava, mas não consigo!! Isto é agoniante! Socorro!!

- (Barulho perturbador do motor do barco)

(voz da baleia) (som de sofrimento da baleia)

(incluir barulhos) - embate da baleia

(voz da baleia) Ai... Não devia ter ido contra aquele barco... Estou ferida!

(voz do peixe-palhaço) Oh não! Temos que procurar ajuda!

(incluir barulhos)

(voz do peixe-palhaço) Tive uma ideia! Hey tu, humano (voz do peixe-palhaço): precisamos de ajuda para parar o barulho que vem dos barcos ...

Toca no barco que está a flutuar acima de nós .

Interação 9 – Sensor E8

Áudio S8

- (Som da baleia a "chorar", a sentir-se em perigo + som dos barcos a fazer barulho, cerca de 10 seg.)

(voz do humano 1) Hey! Há aqui uma baleia a cercar-nos!

(voz do humano 2) Oh! Foi a baleia que veio contra o meu barco, devíamos abatê-la!

(voz do humano 1) Não podemos! Olha, ela parece estar ferida... E está a fazer imenso barulho, parece estar aflita.

(Passados alguns segundos, deixa-se de ouvir o barulho dos barcos)

(voz do peixe-palhaço) Resultou! Obrigada pela ajuda! Estão a desligar os barcos! Já podemos voltar para casa! Já agora ainda estamos um pouco desorientados

Ajudas-nos a voltar? Coloca-nos na tapeçaria da esquerda.

(Ao voltar a colocar a baleia e o peixe-palhaço na tapeçaria da esquerda, será reproduzido um novo áudio)

Interação 10 - Sensor E1 e E3

Áudio S9

(voz da baleia) Ah!! Finalmente! Já estou a ouvir a nossa casa! Já estamos em segurança!!

(voz do peixe-palhaço) Eu também já oiço as anémonas! Vamos!

(pausa)

(narrador) Volte a retirar a baleia e o peixe-palhaço da tapeçaria e coloque-os no pelinto, onde estavam inicialmente.

Interação 11 - Sensor E10

Áudio S10

(voz da baleia) Os meus pais dizem que com o passar dos anos, cada vez mais os humanos têm provocado barulho no oceano... Era tão bom que eles nos entendessem e começassem a reduzir os ruídos... Está tudo nas mãos deles... Hey! Humano! Não te esqueças de passar a mensagem!

(narrador) - Retire os auscultadores e coloque-os onde estavam inicialmente.

Interações Extra

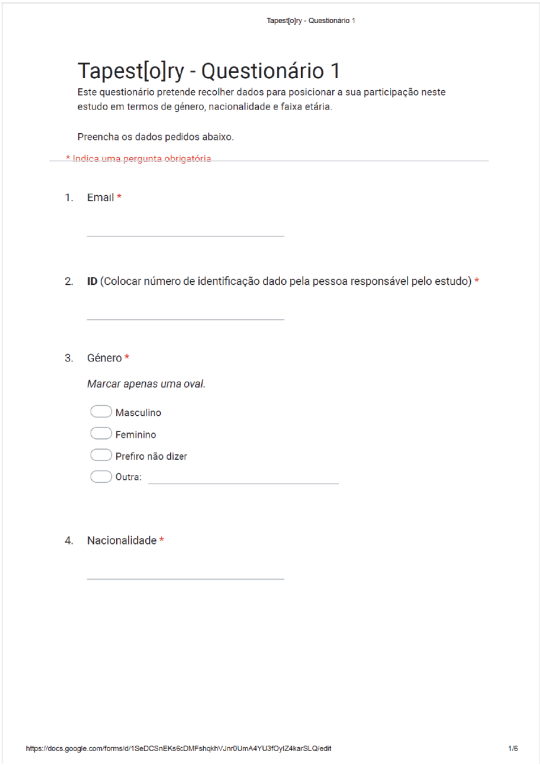
- Corais

- Franjas(pedras)

- Oceano (soundscape do oceano diferente em cada tapeçaria) (escolher uma zona em específico/oceano todo evitando as zonas que já têm intervenção)

- Incluir lixo do lado esverdeado/com intervenção humana + factos sobre eles (?)/sons

C Appendix



Tapest[o]ry - Questionário 1

Tapest[o]ry - Questionário 1

Este questionário pretende recolher dados para posicionar a sua participação neste estudo em termos de género, nacionalidade e faixa etária.

Preencha os dados pedidos abaixo.

* Indica uma pergunta obrigatória

1. Email *

2. **ID** (Colocar número de identificação dado pela pessoa responsável pelo estudo) *

3. Género *

Marcar apenas uma oval.

- Masculino
- Feminino
- Prefiro não dizer
- Outra:

4. Nacionalidade *

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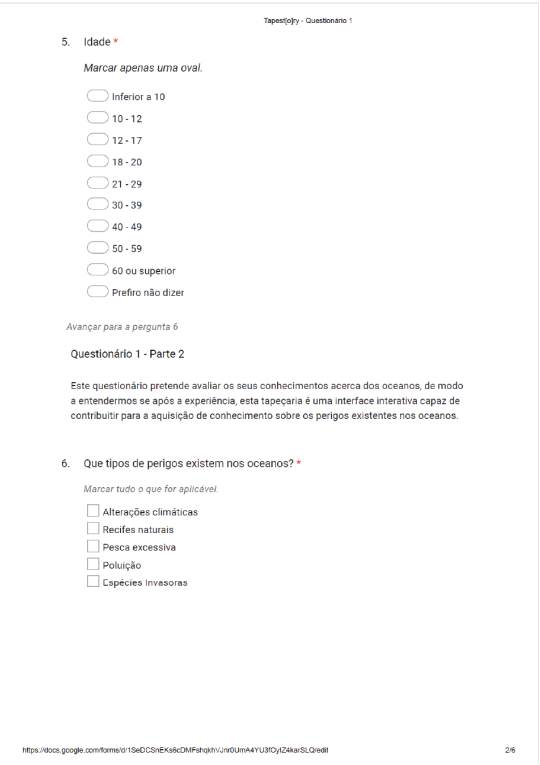

Tapest[o]ry - Questionário 1

5. Idade *

Marcar apenas uma oval.

- Inferior a 10
- 10 - 12
- 12 - 17
- 18 - 20
- 21 - 29
- 30 - 39
- 40 - 49
- 50 - 59
- 60 ou superior
- Prefiro não dizer

Avançar para a pergunta 6

Questionário 1 - Parte 2

Este questionário pretende avaliar os seus conhecimentos acerca dos oceanos, de modo a entendermos se após a experiência, esta tapeçaria é uma interface interativa capaz de contribuitir para a aquisição de conhecimento sobre os perigos existentes nos oceanos.

6. Que tipos de perigos existem nos oceanos? *

Marcar tudo o que for aplicável.

- Alterações climáticas
- Recifes naturais
- Pesca excessiva
- Poluição
- Espécies Invasoras

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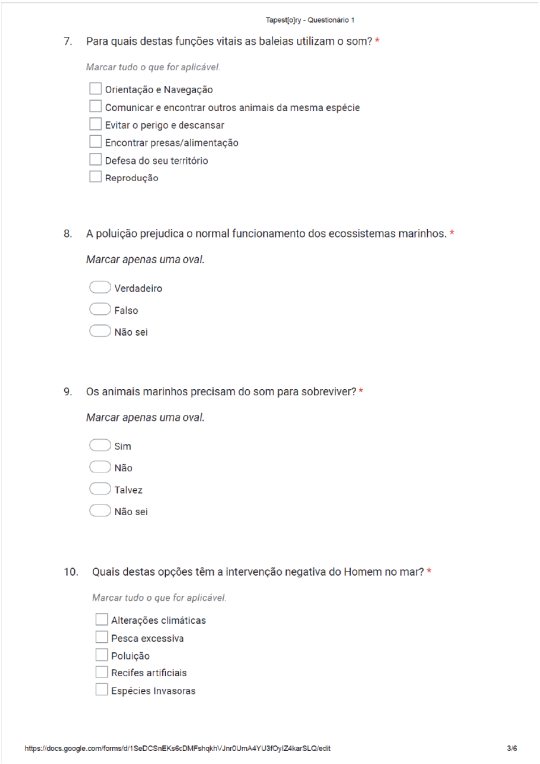

Tapest[o]ry - Questionário 1

7. Para quais destas funções vitais as baleias utilizam o som? *

Marcar tudo o que for aplicável.

- Orientação e Navegação
- Comunicar e encontrar outros animais da mesma espécie
- Evitar o perigo e descansar
- Encontrar presas/alimentação
- Defesa do seu território
- Reprodução

8. A poluição prejudica o normal funcionamento dos ecossistemas marinhos. *

Marcar apenas uma oval.

- Verdadeiro
- Falso
- Não sei

9. Os animais marinhos precisam do som para sobreviver? *

Marcar apenas uma oval.

- Sim
- Não
- Talvez
- Não sei

10. Quais destas opções têm a intervenção negativa do Homem no mar? *

Marcar tudo o que for aplicável.

- Alterações climáticas
- Pesca excessiva
- Poluição
- Recifes artificiais
- Espécies Invasoras

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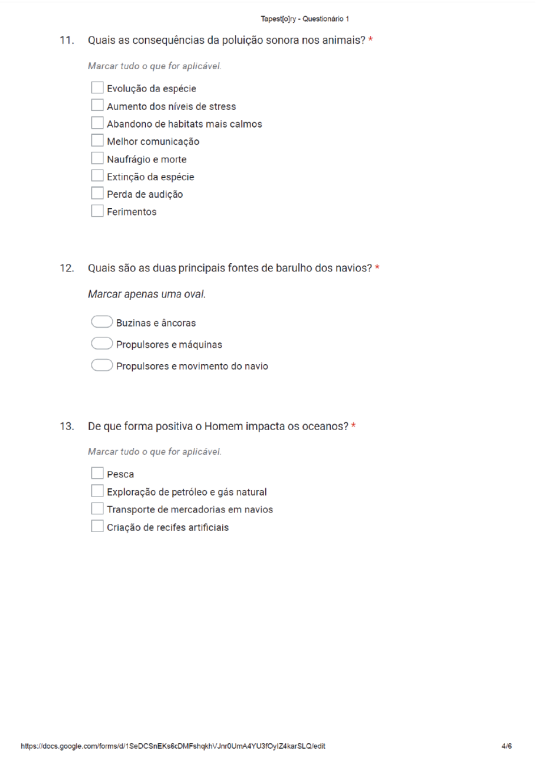

Tapest[o]ry - Questionário 1

11. Quais as consequências da poluição sonora nos animais? *

Marcar tudo o que for aplicável.

- Evolução da espécie
- Aumento dos níveis de stress
- Abandono de habitats mais calmos
- Melhor comunicação
- Naufrágio e morte
- Extinção da espécie
- Perda de audição
- Ferimentos

12. Quais são as duas principais fontes de barulho dos navios? *

Marcar apenas uma oval.

- Buzinas e âncoras
- Propulsores e máquinas
- Propulsores e movimento do navio

13. De que forma positiva o Homem impacta os oceanos? *

Marcar tudo o que for aplicável.

- Pesca
- Exploração de petróleo e gás natural
- Transporte de mercadorias em navios
- Criação de recifes artificiais

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14. Como é que o peixe-palhaço encontra anémonas? *

Marcar apenas uma oval.

- Pelas cores
- Pela forma
- Pelo som
- Pelo cheiro

15. Que tipos de poluição mais afetam os seres vivos marinhos?

Marcar tudo o que for aplicável.

- [ ] Som
- [ ] Lixo
- [ ] Areias
- [ ] Químicos

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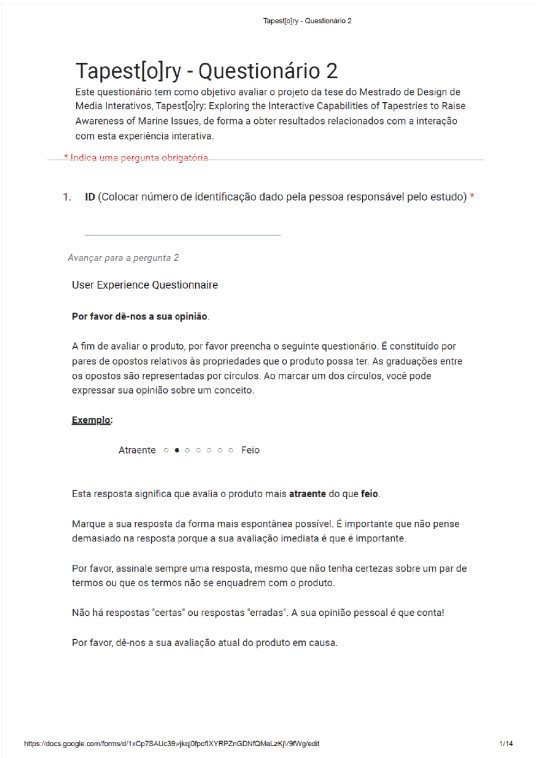
Google Formulários

D Appendix



Tapest[o]ry - Questionário 2

Tapest[o]ry - Questionário 2

Este questionário tem como objetivo avaliar o projeto da tese do Mestrado de Design de Media Interativos, Tapest[o]ry: Exploring the Interactive Capabilities of Tapestries to Raise Awareness of Marine Issues, de forma a obter resultados relacionados com a interação com esta experiência interativa.

* Indica uma pergunta obrigatória

1. **ID** (Colocar número de identificação dado pela pessoa responsável pelo estudo) *

Avançar para a pergunta 2

User Experience Questionnaire

Por favor dê-nos a sua opinião.

A fim de avaliar o produto, por favor preencha o seguinte questionário. É constituído por pares de opostos relativos às propriedades que o produto possa ter. As graduações entre os opostos são representadas por círculos. Ao marcar um dos círculos, você pode expressar sua opinião sobre um conceito.

Exemplo:

Atraente ○ ● ○ ○ ○ ○ ○ Feio

Esta resposta significa que avalia o produto mais **atraente** do que **feio**.

Marque a sua resposta da forma mais espontânea possível. É importante que não pense demasiado na resposta porque a sua avaliação imediata é que é importante.

Por favor, assinale sempre uma resposta, mesmo que não tenha certezas sobre um par de termos ou que os termos não se enquadrem com o produto.

Não há respostas "certas" ou respostas "erradas". A sua opinião pessoal é que conta!

Por favor, dê-nos a sua avaliação atual do produto em causa.

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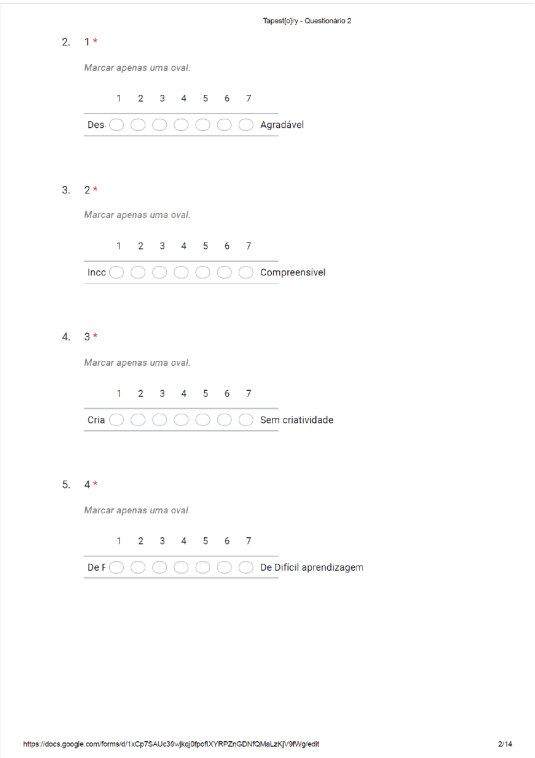

Tapest[o]ry - Questionário 2

2. 1 *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Des	◯	◯	◯	◯	◯	◯	◯	Agradável

3. 2 *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Incc	◯	◯	◯	◯	◯	◯	◯	Compreensível

4. 3 *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Cria	◯	◯	◯	◯	◯	◯	◯	Sem criatividade

5. 4 *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
De F	◯	◯	◯	◯	◯	◯	◯	De Difícil aprendizagem

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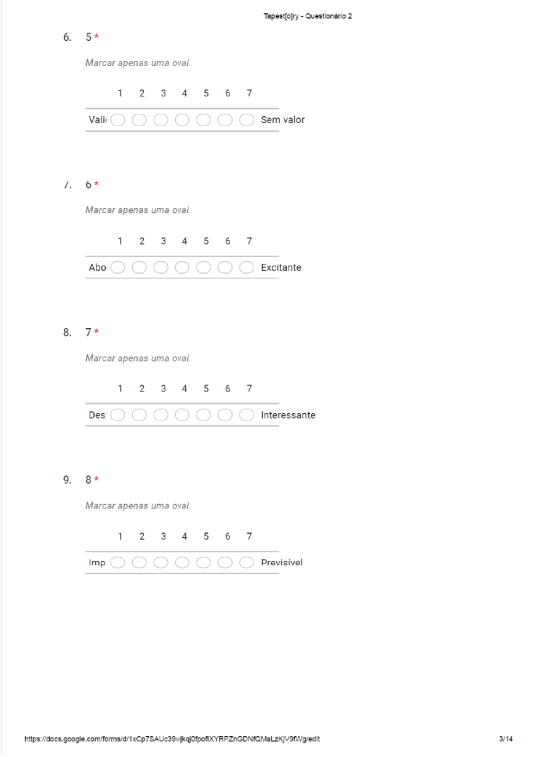

Tapest[o]ry - Questionário 2

6. 5 *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Vali	◯	◯	◯	◯	◯	◯	◯	Sem valor

7. 6 *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Abo	◯	◯	◯	◯	◯	◯	◯	Excitante

8. 7 *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Des	◯	◯	◯	◯	◯	◯	◯	Interessante

9. 8 *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Imp	◯	◯	◯	◯	◯	◯	◯	Previsível

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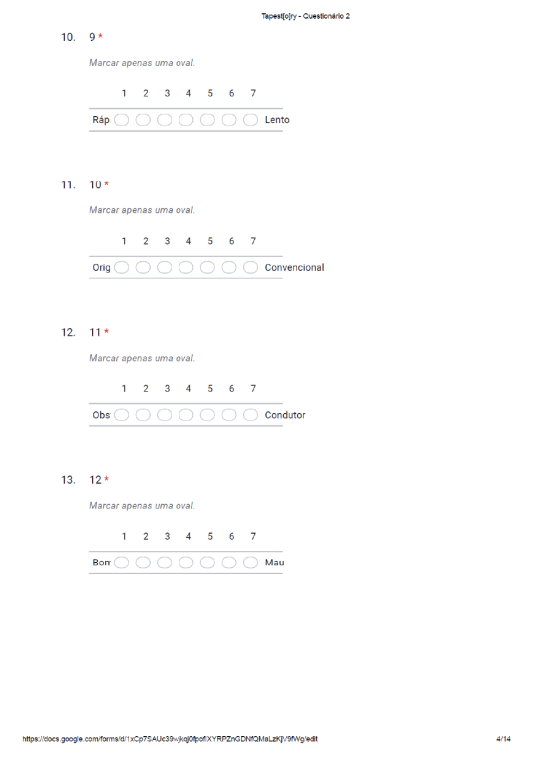

Tapest[o]ry - Questionário 2

10. 9 *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Ráp	◯	◯	◯	◯	◯	◯	◯	Lento

11. 10 *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Orig	◯	◯	◯	◯	◯	◯	◯	Convencional

12. 11 *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Obs	◯	◯	◯	◯	◯	◯	◯	Condutor

13. 12 *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Bom	◯	◯	◯	◯	◯	◯	◯	Mau

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14. 13 *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Com	◯	◯	◯	◯	◯	◯	◯	Fácil

15. 14 *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Des	◯	◯	◯	◯	◯	◯	◯	Atrativo

16. 15 *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Com	◯	◯	◯	◯	◯	◯	◯	Vanguardista

17. 16 *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Incó	◯	◯	◯	◯	◯	◯	◯	Cómodo

18. 17 *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Segu	◯	◯	◯	◯	◯	◯	◯	Inseguro

19. 18 *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Mot	◯	◯	◯	◯	◯	◯	◯	Desmotivante

20. 19 *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Ater	◯	◯	◯	◯	◯	◯	◯	Não atende às expectativas

21. 20 *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Inefi	◯	◯	◯	◯	◯	◯	◯	Eficiente

22. 21 *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Evid	◯	◯	◯	◯	◯	◯	◯	Confuso

23. 22 *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Imp	◯	◯	◯	◯	◯	◯	◯	Prático

24. 23 *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Orga	◯	◯	◯	◯	◯	◯	◯	Desorganizado

25. 24 *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Atra	◯	◯	◯	◯	◯	◯	◯	Feio

26. 25 *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Sim	◯	◯	◯	◯	◯	◯	◯	Antipático

27. 26 *

Marcar apenas uma oval.

	1	2	3	4	5	6	7	
Con	◯	◯	◯	◯	◯	◯	◯	Inovador

Avançar para a pergunta 28

Satisfação enquanto conteúdo educacional - (a partir do EGamesFlow Questionnaire)

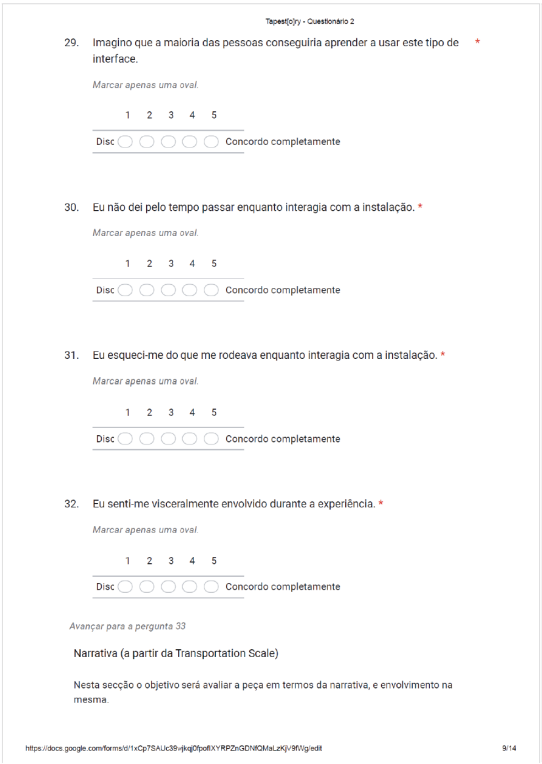
Nesta secção o objetivo será avaliar a peça em termos de satisfação enquanto conteúdo educacional.

A fim de avaliar esta intalação, por favor preencha o seguinte questionário.
Deve selecionar um dos círculos entre **Discordo por completo** e **Concordo completamente**, consoante a sua opinião em relação a cada afirmação.

28. Achei a tapeçaria desnecessariamente complexa. *

Marcar apenas uma oval.

	1	2	3	4	5	
Disc	◯	◯	◯	◯	◯	Concordo completamente



Tapest[o]ry - Questionário 2

29. Imagino que a maioria das pessoas conseguiria aprender a usar este tipo de interface. *

Marcar apenas uma oval.

1 2 3 4 5

Disc ◯ ◯ ◯ ◯ ◯ Concordo completamente

30. Eu não dei pelo tempo passar enquanto interagia com a instalação. *

Marcar apenas uma oval.

1 2 3 4 5

Disc ◯ ◯ ◯ ◯ ◯ Concordo completamente

31. Eu esqueci-me do que me rodeava enquanto interagia com a instalação. *

Marcar apenas uma oval.

1 2 3 4 5

Disc ◯ ◯ ◯ ◯ ◯ Concordo completamente

32. Eu senti-me visceralmente envolvido durante a experiência. *

Marcar apenas uma oval.

1 2 3 4 5

Disc ◯ ◯ ◯ ◯ ◯ Concordo completamente

Avançar para a pergunta 33

Narrativa (a partir da Transportation Scale)

Nesta secção o objetivo será avaliar a peça em termos da narrativa, e envolvimento na mesma.

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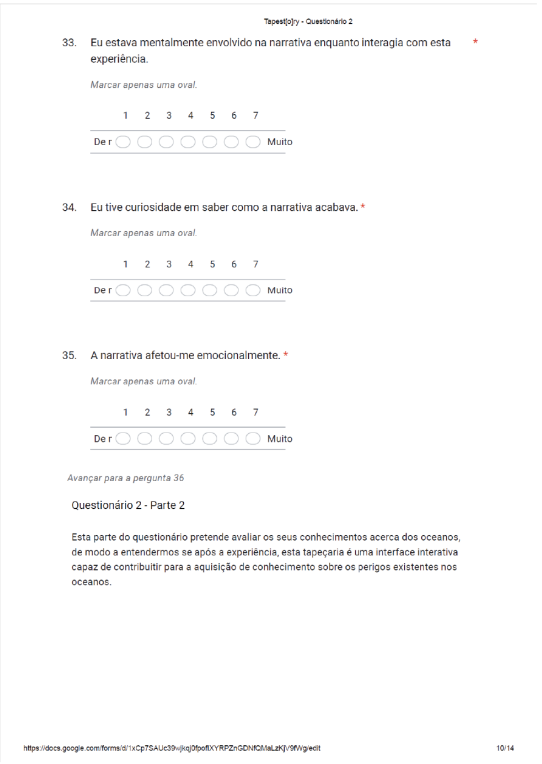

Tapest[o]ry - Questionário 2

33. Eu estava mentalmente envolvido na narrativa enquanto interagia com esta experiência. *

Marcar apenas uma oval.

1 2 3 4 5 6 7

De r ◯ ◯ ◯ ◯ ◯ ◯ ◯ Muito

34. Eu tive curiosidade em saber como a narrativa acabava. *

Marcar apenas uma oval.

1 2 3 4 5 6 7

De r ◯ ◯ ◯ ◯ ◯ ◯ ◯ Muito

35. A narrativa afetou-me emocionalmente. *

Marcar apenas uma oval.

1 2 3 4 5 6 7

De r ◯ ◯ ◯ ◯ ◯ ◯ ◯ Muito

Avançar para a pergunta 36

Questionário 2 - Parte 2

Esta parte do questionário pretende avaliar os seus conhecimentos acerca dos oceanos, de modo a entendermos se após a experiência, esta tapeçaria é uma interface interativa capaz de contribuitir para a aquisição de conhecimento sobre os perigos existentes nos oceanos.

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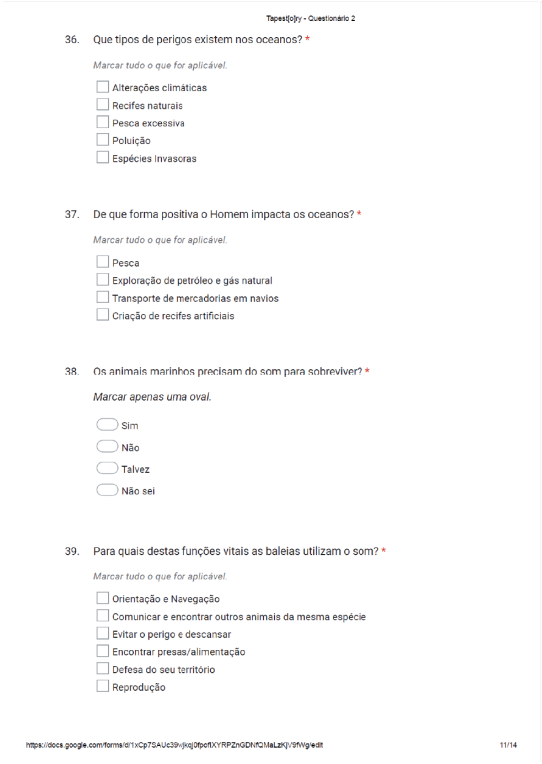

Tapest[o]ry - Questionário 2

36. Que tipos de perigos existem nos oceanos? *

Marcar tudo o que for aplicável.

- ☐ Alterações climáticas
- ☐ Recifes naturais
- ☐ Pesca excessiva
- ☐ Poluição
- ☐ Espécies Invasoras

37. De que forma positiva o Homem impacta os oceanos? *

Marcar tudo o que for aplicável.

- ☐ Pesca
- ☐ Exploração de petróleo e gás natural
- ☐ Transporte de mercadorias em navios
- ☐ Criação de recifes artificiais

38. Os animais marinhos precisam do som para sobreviver? *

Marcar apenas uma oval.

- ◯ Sim
- ◯ Não
- ◯ Talvez
- ◯ Não sei

39. Para quais destas funções vitais as baleias utilizam o som? *

Marcar tudo o que for aplicável.

- ☐ Orientação e Navegação
- ☐ Comunicar e encontrar outros animais da mesma espécie
- ☐ Evitar o perigo e descansar
- ☐ Encontrar presas/alimentação
- ☐ Defesa do seu território
- ☐ Reprodução

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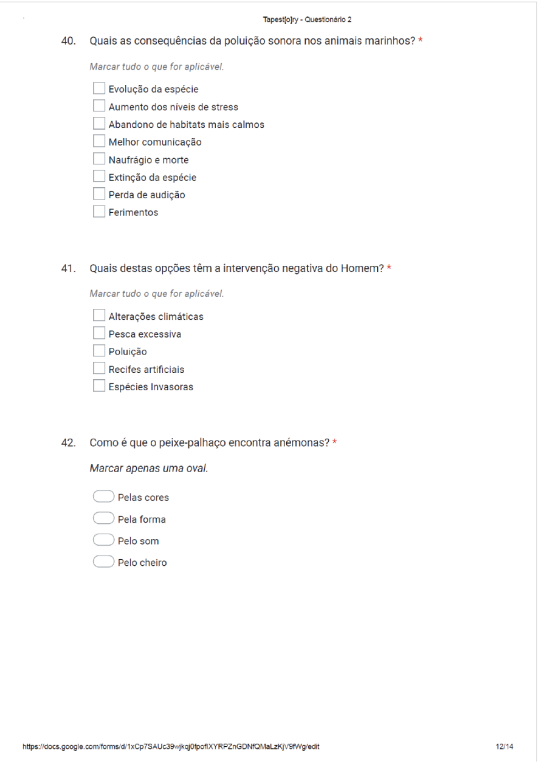

Tapest[o]ry - Questionário 2

40. Quais as consequências da poluição sonora nos animais marinhos? *

Marcar tudo o que for aplicável.

- ☐ Evolução da espécie
- ☐ Aumento dos níveis de stress
- ☐ Abandono de habitats mais calmos
- ☐ Melhor comunicação
- ☐ Naufrágio e morte
- ☐ Extinção da espécie
- ☐ Perda de audição
- ☐ Ferimentos

41. Quais destas opções têm a intervenção negativa do Homem? *

Marcar tudo o que for aplicável.

- ☐ Alterações climáticas
- ☐ Pesca excessiva
- ☐ Poluição
- ☐ Recifes artificiais
- ☐ Espécies Invasoras

42. Como é que o peixe-palhaço encontra anémonas? *

Marcar apenas uma oval.

- ◯ Pelas cores
- ◯ Pela forma
- ◯ Pelo som
- ◯ Pelo cheiro

https://docs.google.com/forms/d/1xCp7SAUc39vjkqj0fpofiXYRPZnGDNfQMaLzKjV9fWg/edit 12/14

43. A poluição prejudica o normal funcionamento dos ecossistemas marinhos. *

Marcar apenas uma oval.

- Verdadeiro
- Falso
- Não sei

44. Quais são as duas principais fontes de barulho dos navios? *

Marcar apenas uma oval.

- Buzinas e âncoras
- Propulsores e máquinas
- Propulsores e movimento do navio

45. Que tipos de poluição mais afetam os seres vivos marinhos?

Marcar tudo o que for aplicável.

- [ ] Som
- [ ] Lixo
- [ ] Areia
- [ ] Químicos

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Google Formulários

E Appendix

Protocolo Guião - Estudo Piloto

1. **Objetivos Do Estudo**
   1. Verificação de dados demográficos para fins de estatística, e verificação da eficácia da tapeçaria enquanto meio educacional: dar conhecimento acerca dos perigos no mar;
      i. Questionário 1 (inicial) – demográfico + questões sobre os oceanos;
   2. Observar o comportamento do utilizador com a peça;
      i. Observação;
      ii. Gravação de vídeo e áudio;
      iii. Think-aloud;
      iv. Tirar notas;
   3. Avaliar a usabilidade, interação e experiência com a peça, para entender se esta tapeçaria pode ser uma interface interativa;
      i. Questionário UEQ;
      ii. Questionário 2 – questões sobre os oceanos;
   4. Verificar se o utilizador entendeu os conceitos da peça através da narrativa.
      i. Pequena entrevista sobre a interação com a peça e narrativa.

2. **Material Necessário**
   1. Formulários de consentimento;
   2. 1 computador para preenchimento dos questionários;
   3. Tapeçaria + peças do plinto;
   4. Plintos (suportar as peças);
   5. Bare Conductive Touch Board;
   6. Auscultadores;
   7. Cabo para extensão dos auscultadores;
   8. Cabo longo para ligar a Bare Conductive Touch Board;
   9. Extensão (se necessário)
   10. Máquina fotográfica para recolha de vídeo;
   11. Telemóvel/iPad para recolha de áudio;
   12. Caderno/iPad para tirar notas.

3. **PROCEDIMENTOS A CUMPRIR DURANTE O ESTUDO**
   1. **Apresentação e Saudações**

Olá, o meu nome é Laura Santos, e hoje vou conduzir este estudo piloto sobre o projeto desenvolvido para a minha tese de mestrado. Em primeiro lugar, quero agradecer o seu tempo e disponibilidade.

   2. **Explicar o Projeto**

Durante este projeto, desenvolvi uma tapeçaria interativa, que permite detetar o toque através de sensores. Ao tocar nos vários sensores, irá conhecer uma narrativa que pretende alertar para perigos no mar.

   3. **Explicar como se processa o estudo**

Em primeiro lugar, vai preencher um questionário dividido em duas partes: o primeiro é um pequeno questionário demográfico para fins estatísticos (os dados serão sempre anónimos). A segunda parte do questionário terá perguntas sobre o oceano.

Em seguida vai interagir com a peça, (enquando me vai dizendo o que está a pensar, durante a interação). Vou estar a recolher som e imagem, se me permitir, para o caso de haver alguma situação que eu precise de analisar melhor. Estas gravações serão apenas utilizadas para a avaliação e análise dos resultados deste projeto.

Após a interação, vou pedir-lhe para preencher o User Experience Questionnaire, para avaliar a peça em termos de usabilidade e interação. Em seguida, algumas questões relacionadas com o flow da experiência e também terá mais um pequeno questionário sobre os perigos nos oceanos, seguido de mais algumas questões sobre a peça e interação com a mesma.

Estarei disponível para responder a questões acerca deste projeto, quer durante o este estudo, quer após a finalização do mesmo.

   4. **Pedir folha de consentimento assinada (cerca de 5 min.)**

Agora vou pedir-lhe que leia atentamente este formulário de consentimento, e que o assine.

- Criar/dar número de participante

Para cada participante será atribuído um número, após a assinatura do formulário, garantindo assim a sua confidencialidade.

O seu número será o XXX

5. **Questionário 1 – Google forms (5 min)**
   https://docs.google.com/forms/d/e/1FAIpQLSeUOtAzJKsbjPY8wuhBhwaQujeaNQ1A4suWFvPErkPj_SGW8A/viewform

Então vamos dar início ao estudo. Vou pedir que preencha este questionário (abrir google forms) antes de interagir com a peça. A sua identificação será o número XXX, que lhe atribuí na folha de consentimento. A primeira parte do questionário serve para recolher dados demográficos para fins estatísticos e a segunda, serve para sabermos como está o seu conhecimento sobre os perigos no oceano, antes de interagir com a peça.

6. **Explicar comportamentos importantes – Interação com a peça**
   i. **Em caso de think Aloud**
   Para este caso, o participante terá que dizer o que está a pensar durante a interação com a peça, enquanto eu vou estar a tirar notas/gravar.
   A peça e o participante devem conseguir trabalhar sozinhos.
   O participante deve chamar apenas em caso de extrema necessidade.
   Eu devo evitar dar dicas, ou dizer o que deve fazer.
   Só ajudo se realmente for mesmo necessário.
   ii. **Sem think aloud**
   Neste caso o participante vai estar a interagir com a peça sozinho, enquanto eu tiro notas e gravo.
   A peça e o participante devem conseguir trabalhar sozinhos.
   O participante deve chamar apenas em caso de extrema necessidade.
   Eu devo evitar dar dicas, ou dizer o que o participante deve fazer.
   Só ajudo se realmente for mesmo necessário.

7. **Interação com a peça (7 min)**
   (Gravar vídeo/áudio)

Agora que já preencheu os primeiro questionário, vou pedir que se dirija à peça e que dê início à experiência. Relembro que a peça deve funcionar completamente sem a minha ajuda, e por isso, peço que só me chame apenas caso realmente aconteça alguma coisa que o impeça de avançar.

Tomar notas do que utilizador faz/diz.

8. **Questionário 2 (10 min)**
   https://docs.google.com/forms/d/e/1FAIpQLScuBK-B3En2sjMHfnjqBw5MFaY35gCPJuuFqMx4T4b_muYnjQ/viewform
   i. **UEQ + Egame Flow + Transportation scale**

Agora, vou pedir que preencha o questionário dois, onde vai encontrar 3 escalas de avaliação diferente, a User Experience Questionnaire, o eGame Flow, e a transportation scale, que pretendem avaliar a interação, a usabilidade, a narrativa. E ainda mais um questionário sobre os perigos nos oceanos.

O seu número de identificação é o XXX.

Abrir formulário no google forms.

9. **Entrevista (5 min)**

Agora gostava de fazer algumas questões sobre a peça e a interação com a mesma. (gravar áudio)

(principais)

- Quais são as diferenças notórias entre cada peça da tapeçaria? Por favor, explique.
(em caso de precisar de puxar assunto, insisto com: **Cores? Texturas?**)
- Que elementos foram mais, ou menos apelativos de tocar? Porquê?
- Sentiu que teve poder de decisão ao interagir com a peça? De que modo?
- Alguma vez interagiu com uma narrativa interativa através do toque? (caso a pessoa esteja na disposição de falar)
-Se sim, quais? Alguma delas utilizava materiais têxteis?
- O que achou das instruções serem dadas pelos áudios?

Perguntas extra de coisas que quereria saber, por curiosidade (talvez ainda adiciono mais):

- Na sua opinião qual é o conceito ou tema central desta tapeçaria?
- Acha que a instalação adota uma abordagem única e inovadora ao tema ou à tapeçaria?
- Acha que os diferentes elementos (história, visual, tecnologia) são claros e consistentes ou é desarticulada?
- Em geral, a peça parece coesa ou parece desarticulada?
- Que tipo de reações/emoções a peça provocou em si?
- Existe um senso de coerência e consistência em termos de estilo, paleta de cores ou outros elementos visuais?

-Faria alguma alteração na peça?

-Sentiu mais empatia com que personagem? (aqui meio que fico a entender se a pessoa entendeu que personagem era qual)

-O que sentiu em relação à duração da experiência?

10. **Agradecer a participação, entregar recompensa**

    Chegámos ao fim do estudo. Agradeço imenso pela colaboração e disponibilidade. O que recolhi será imprescindível para a conclusão da minha tese.

    Chocolates

4. OBSERVAÇÃO

1. Expressão facial e corporal ao interagir com a peça;
2. O utilizador parece conseguir interagir com a peça facilmente;
3. O utilizador pede ajuda muitas vezes?
    i. Em que momentos pede ajuda?
4. Comentários feitos durante a interação.