Tapest[o]ry: Promoting Marine Noise Pollution Awareness through an Interactive Tangible Tapestry

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Figure 1: Tapest[o]ry: Details of the Interaction with the Interactive Tapestry.

Abstract

Our ancestors communicated stories through tapestries, using them to adorn public and private spaces. Traditionally, these tapestries were static artworks hanging on walls without audience interaction. Nevertheless, textiles offer a versatile medium, crafted from diverse materials and colours and manipulated to produce unique, touch-responsive textures. Our work integrates the tactile capabilities of weaving with capacitive sensor technology to create an interactive art installation that fosters non-formal learning and raises awareness about marine noise pollution and its harmful effects on marine ecosystems. Marine animals, particularly cetaceans, rely heavily on sound for communication, navigation, and hunting. Noise pollution disrupts these essential functions, presenting severe threats to their survival. By harnessing the storytelling potential of tapestries and the power of capacitive sensors connected to a microcontroller, we developed a unique and immersive art installation that educates the public and decision-makers about these pressing issues. This study evaluates the impact of this interactive tapestry on its audience. Qualitative and quantitative results suggest valuable insights, showcasing that Tapest[o]ry engages participants through its tangible storytelling interface, fostering emotional responses such as empathy and compassion. Participants shared their thoughts about awareness of marine noise pollution, demonstrating the possible use of interactive art installations as storytelling tools. Our findings highlight the potential of integrating traditional textile techniques with interactive technology and storytelling to create powerful educational experiences outside formal learning environments, encouraging personal reflection and support for environmental issues.

CCS Concepts

• **Human-centered computing**; • **Interaction design**; • **Empirical studies in interaction design**;

Keywords

Tapestry, Interactive art installations, Tangible interfaces, Interactive Tangible Tapestry, Marine biodiversity awareness, Noise pollution, Capacitive sensors

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1 Introduction

Through the years, storytelling has played a crucial role in the culture and history of human beings as a medium for sharing knowledge, evoke emotions, and raise connections. It is a powerful tool to promote engagement and enhance learning, particularly in informal contexts. As technology is evolving, the integration of interactive media facilitates the way the stories are told, opening possibilities for the audience to participate and personalize the narrative, and enrich experiences with the use of multisensory features [17].

Tangible User Interfaces (TUIs) introduce innovative tools that challenge the bridge between the physical and digital worlds. TUIs create more immersive experiences through their tactility and spatial interaction with physical artefacts, making them a great tool for learning, promoting more engagement and exploration [19, 25]. Even though TUIs have potential characteristics, it is still important to understand how this type of interface can successfully support storytelling and learning outcomes, especially when integrated into artefacts like a weaving tapestry.

To contribute to this field, we designed an interactive tapestry as a tool for storytelling by seamlessly integrating technology within the weaving tapestry technique. We invite the audience to physically and emotionally engage with the interactive piece, being responsible for the narrative continuity and making the storytelling experience more interactive.

Hence, this research investigates the following questions:

RQ1: How do design elements of an interactive tapestry impact user interaction and intuitive navigation?

RQ2: Can an interactive tangible tapestry promote awareness of marine noise pollution?

RQ3: How can we optimise the integration of conductive materials within traditional tapestry techniques to ensure reliable performance and user satisfaction?

This study aims to evaluate this interactive tapestry in terms of usability, user engagement, and learning potential with the use of an interactive tapestry, contributing to the evolution of TUIs and their integration into traditional tapestries for storytelling and future interactive storytelling projects.

2 Related Work

Interactive storytelling focuses on playing with how the audience will perceive the narrative, whether predetermined or not. It is necessary to balance how to control the narrative between the author, which gives the components to build the story, and the audience, which can shape the story outcome [8, 39]. Current research within tangible storytelling explores systems' properties to explore interactive gestures or advanced technological spaces, but a small quantity presents the exploration of tangible storytelling using itself as a medium for storytelling. Tangible storytelling user interfaces commonly use embedded digital capabilities as in Letters to José [11, 17]. In our project, the user is responsible for conducting the narrative by following the narrator and characters' instructions; otherwise, the experience would not continue.

TUIs, a Human-Computer Interaction (HCI) topic, frequently uses physical gestures to engage the user, considering the embodiment concept, which gives attention to human behaviours, user experience and physicality since it is intrinsically connected to the use of gesture helping to find solutions [19, 25]. Moreover, human beings have always used the sense of touch to explore the world, leading them to relate emotions to textures [3]. The tactile qualities of a material play a crucial role in shaping emotional responses to an artwork [42]. The consciousness of these aspects is relevant to facilitate learning outcomes [25], as through the sense of touch, users can create connections to the content. The use of textures (refers to the quality and the surface of the fabrics) can evoke psychological and emotional connections. In a recent study, the authors identify softer materials as being able to stimulate positive emotions [45]. A surface's texture, softness, roughness, or warmth can evoke feelings of comfort, tension, or nostalgia, influencing how the viewer connects with the piece. A smooth, delicate texture may invite a sense of intimacy and warmth, while a coarse, rigid surface might create a feeling of unease or resistance. By engaging the sense of touch, materials become powerful emotional expressions and interpretation conduits [42].

Education comes in several ways, each important to the personal and professional development of each human being: 1) formal learning, 2) non-formal learning and 3) informal learning. 1) Formal learning focuses on the learning structure planned and guided by institutions like schools. This type of learning follows a predefined curriculum to acquire specific knowledge and complete certain goals; 2) Non-formal learning is learning acquired outside the formal educational settings. It is usually organised and has more flexible goals, and 3) Informal learning is spontaneous learning acquired through our daily experiences. It is not planned and has no specific goals [26]. Some examples of projects that facilitate non-formal learning are Letters to José [10, 11], Crafting Stories[32], Arpilleras Parlantes [16], Emotions Speaking [36], and BeadED Adventures [40].

Aasbakken states that interactive art installations and traditional art are similar since they are physical constructions typically exhibited in public spaces for audience appreciation [1]. The traditional way to experience art is, that the artist creates his artwork, and the audience observes the result. However, interactive art challenges this barrier, inviting the audience to have a crucial role in creating the artwork and fostering collaboration and inclusion in the experience. Each experience of the artwork might have different results and unique interpretations. Engaging the audience through physical, emotional and intellectual ways creates a stronger connection between the viewer and the artwork, making the experience more immersive and impactful [13].

A tapestry is an ancestral craft technique used throughout the years for utilitarian purposes and as a contemplative element to adorn elite spaces, frequently highlighting its storytelling potential [43] and, more recently, to the exploration of different materials, textures, and shapes [22, 24, 30, 41], bringing a new life to the practice of this technique, and visual affordances potential to facilitate the user experience, as TUIs often use [25]. Moreover, contemporary textile artists [4, 20, 23] use their art to showcase their

concerns, convey important messages, and make their audience reflect on them. We considered these tapestry features to create our interactive tapestry.

Evaluating the user experience with interactive art, and interactive art where a narrative employs a crucial role, demands evaluating several important aspects. The following examples showcase different approaches used for interactive art interaction evaluation. Hook et al. note that while HCI employs formal user studies to evaluate computational systems, art evaluation typically relies on criticism, with a limited focus on users. They propose interactive art evaluation by videotaping participants during an interaction and conducting open interviews with a set of questions [18]. Similarly, Bilda et al. emphasise the importance of evaluating the user's behaviour and thoughts during the interaction. Their approach uses video observation and a semi-structured interview where they ask some initial opinions, followed by some questions [5]. Furthermore, Morreale et al. showcase a mixed-method evaluation, integrating field observations, interviews, questionnaires, log data, and video record analysis. This method allowed a better understanding of the participants' behaviour and engagement [28]. Echeverri et al. explored a mixed method for the evaluation of Letters to José, where they used a combination of open-ended questions, surveys on engagement, narrative transportation, and agency, and a semi-structured interview covering narrative aspects such as play, performance and interactivity. This approach provided a more holistic view of the participants' experiences [9]. Moreover, Morrison et al. also explored several methods, such as shadowing, interviews and informal discussion, which according to the authors might bring a deeper understanding of evaluating engagement in interactive art installations [29].

Overall, the Tapest[o]ry's specific combination of medium, technology, theme, interaction design, and evaluation focus distinguishes it from the other TUIs' storytelling systems contribution to the field. We can unpack this distinction between the current related work in the following way:

- The use of a traditional weaving tapestry as the primary interface and storytelling medium - While other TUI storytelling systems utilise various physical artefacts and textiles [16, 32], Tapest[o]ry embeds conductive materials (threads and fibres) into the weaving and felting techniques - something that is quite different from other TUI systems as the integration of conductive materials in the weaving techniques has not been explored before in this way.
- The focus on environmental awareness sets Tapest[o]ry apart from other related works with different themes or purposes [10, 16, 32, 36, 40]. We designed the narrative and interactive elements to educate the public about the harmful effects of noise pollution on marine ecosystems, particularly cetaceans. Furthermore, how we use the compelling multisensory experience to raise this awareness is quite different from other TUI's. In Tapest[o]ry, users not only touch and see the tapestry but also listen to a narrative told by characters and a narrator, along with ambient ocean sounds. The specific combination of sensory modalities enhances immersion and engagement with the story and its awareness message. Furthermore, the audience's active role in the narrative continuity is unique, where the user is responsible for conducting the narrative by following instructions and sequentially touching interaction points on the tapestry. This level of user agency in progressing the story distinguishes it from systems where the narrative might unfold more passively [16, 32] or through different interaction mechanisms [10, 32, 36, 40].
- Tapest[o]ry's evaluation goes beyond the current RW, adding a concrete example of how established HCI evaluation tools can be used to assess interactive art installations that incorporate storytelling through tangible interfaces.

3 Designing Tapest[o]ry

In the initial phase of this project, we extensively detailed the concept, design and execution of Tapest[o]ry in a previous publication [37]. In the following section, we summarise our concept and design process for combining tapestry, technology, the marine noise pollution theme, storytelling and user experience.

3.1 Theme Conceptualisation

Our motivation was based on the rich tapestries' potential to tell stories throughout the years and their ability to raise awareness of critical issues. Combining embodied interaction allows us to transform art into a living, interactive experience, making viewers active participants in its creation and exploration. Merging tapestries' tactile and visual appeal with immersive audio, we aim to create a compelling medium to discuss marine noise pollution and its effects on marine biodiversity.

Anthropogenic sounds significantly disrupt whales and other cetaceans, whose communication relies on high-pitched sounds that travel long distances. This human-generated noise is louder and more disruptive, deeply impacting marine ecosystems. Whales play a crucial role in these ecosystems by storing large amounts of carbon dioxide, helping to mitigate climate change [2, 7, 12, 21, 27].

Through this tapestry, we aim to amplify the voices of marine life, inspire conversations about pressing issues, and inspire sustainable actions to protect marine ecosystems.

3.2 Design Iterations

The development of this interactive tapestry required several design iterations, focusing on how users would engage with the tapestry and how to convey the story effectively to highlight the issue of marine noise pollution.

We sketched ideas while building the narrative and designing the user journey. These steps helped us envision the tapestry's world and how users would unveil the story through interaction. Tapest[o]ry comprises three woven pieces and two felted characters (a whale and a clownfish) portrayed as improbable friends who face challenges in the noisy ocean. The user helps the characters overcome these challenges through interactive engagement. By giving them human-like characteristics, we aimed to humanise the impact of marine noise pollution and evoke empathy, fostering a sense of responsibility to protect the oceans.

The narrative follows Freytag's Pyramid [44], a traditional storytelling structure where we align key interaction points with emotional tension and resolution events. This approach aims to encourage the audience to actively participate in the story and create a deeper emotional connection.

To deliver the narrative, we used audio transmitted through headphones. The characters speak directly to the user while hearing ambient ocean sounds, immersing the audience in the underwater world.

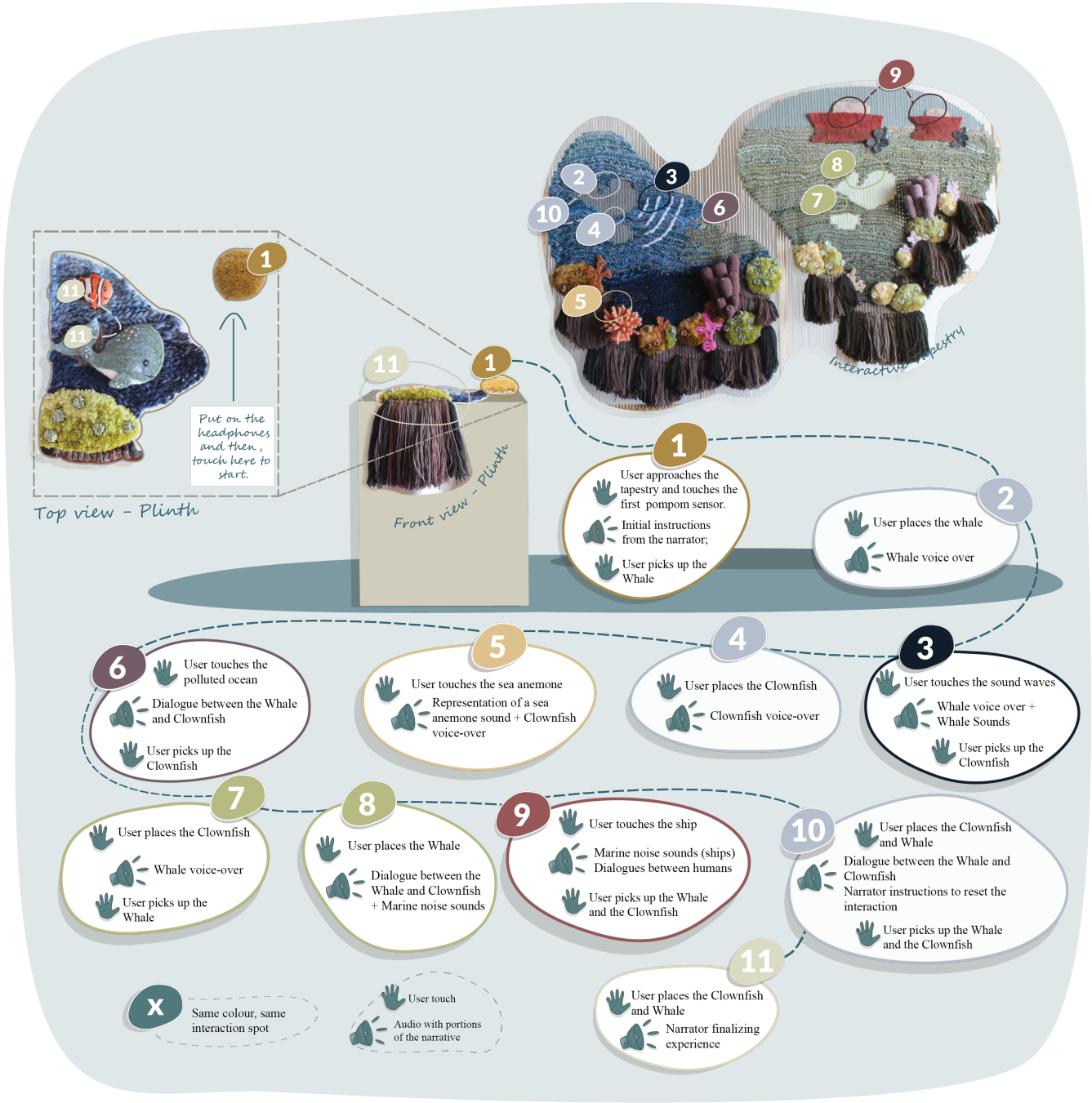

Figure 2: Tapest[o]ry: Expected User Interaction. This illustration demonstrates how we planned the user experience, starting with an initial phase, where the story plot takes place, in the healthy ocean (from interaction spot number 1 to 6); a second phase, where the story unfolds in the unhealthy ocean (from interaction spot number 7 to 9); and finally, the last phase, back to the healthy ocean (interaction spot numbers 10 and 11)

3.3 Interaction

To create an interactive tapestry, we seamlessly integrated conductive materials, such as conductive threads and fibre, into the weaving and felting techniques. These materials were connected to a Bare Conductive Touch Board [6], which enabled touch detection and triggered audio feedback. The audio included the narrative told by the narrator and characters, enhancing the immersive experience.

Each interaction point on the tapestry corresponds to a specific portion of the narrative. When the user sequentially touches these points, they receive audio instructions to continue the storyline. Figure 2 illustrates this setup, showing the eleven interaction points and the feedback, the user will receive. We planned the interaction, expecting it to be between *6 minutes and 30 seconds* and *7 minutes*, keeping in mind the duration of the interactive tapestry audio and the user actions.

3.4 Textile Materials

To create a large tapestry, we needed a significant amount of wool. Following our sustainable approach and the project's environmental theme, we secure this approach by contacting the community, asking for wool they no longer used, and reusing the textiles that otherwise might have been discarded. This effort yielded several portions of wool in various colours and sizes. The collected wool was also complemented by the local artisanal institute.

In the end, we also supplemented this with roving wool for the felting technique and colourful fabrics for the fabric manipulation technique.

This sustainable approach reduced waste and added a meaningful context to the project, highlighting the importance of collective effort in addressing environmental challenges.

4 Tapest[o]ry Prototype Evaluation

Since the beginning, this research effort has 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 ask for a mix-method evaluation [1, 9, 18, 28, 29]. As such, to evaluate the interaction with our piece, we collected data using 1) questionnaires, 2) observation allied with taking notes, 3) interaction time, and 4) Semi-structured interviews with taking notes (see Figure 3).

4.1 Protocol and Metrics

Participants were recruited using a convenience sampling method [15]. We conducted an exploratory study in a room used only for the study (see Figure 4). We recruited 26 participants, explained the study process, and handed each participant a consent form. We then assigned each participant an ID number to anonymise their data.

We started with a pre-experience questionnaire to gather demographic data (age and gender). We then gathered answers to ten questions about the main theme of our tapestry, the ocean – five general questions inspired by existing questionnaires [33, 34], and five others to analyse if they might increase their knowledge from the interactive tapestry narrative (for this purpose, the same questions were used before and after the interaction with the piece, but in random order). The Ocean Knowledge Assessment questionnaire was composed of the following questions:

- Q1 – What types of dangers exist in the oceans? (multiple choice answer) – This question has a total score of *10 points*, where each correct option scores *2,5 points*, and a wrong answer scores *0 points*;
- Q2 – For which of these vital functions do whales use sound? (multiple choice answer) – This question has a total score of *10 points*, where each correct option scores *1,67 points*, and a wrong answer scores *0 points*;
- Q3 – Pollution harms the normal functioning of marine ecosystems. (true or false answer) – This question has a total score of *10 points*, and a wrong answer scores *0 points*;
- Q4 – Do marine animals need sound to survive? (multiple choice answer) – This question has a total score of *10 points*, and in case of answering "Maybe", it scores *5 points*, and a wrong answer scores *0 points*;
- Q5 – Which of these options has a negative intervention in the sea? (multiple choice answer) – This question has a total score of *10 points*, where each correct option scores *2,5 points*, and a wrong answer scores *0 points*;
- Q6 – What are the consequences of noise pollution in animals? (multiple choice answer) – This question has a total score of *10 points*, where each correct option scores *2 points*, and a wrong answer scores *0 points*;
- Q7 – What are the two main sources of noise on ships? (multiple choice answer) – This question has a total score of *10 points*, and a wrong answer scores *0 points*;
- Q8 – How does man positively impact the oceans? (multiple choice answer) – This question has a total score of *10 points*, and a wrong answer scores *0 points*;
- Q9 – How does the clownfish find the anemones? (multiple choice answer) – This question has a total score of *10 points*, and a wrong answer scores *0 points*;
- Q10 – What types of pollution most affect marine life? (multiple choice answer) – This question has a total score of *10 points*, where each correct option scores *3,34 points*, and a wrong answer scores *0 points*.

The participants were then asked to interact with the interactive tapestry individually. Following the audio instructions, they had to interact with the tapestry, and help was only provided in extremely difficult situations. We also asked each participant to think aloud

Figure 3: Study Protocol

Figure 4: Placement of the interactive tapestry for the Study

during the interaction. At the same time, we took observation notes related to their behaviour, such as their facial and body expressions, comments, and reactions, to the narrative and tasks.

Finally, we gave the participants the post-questionnaire. This questionnaire compiled three scales:

1) the User Experience Questionnaire (UEQ) [31], a 7 Likert scale, between -3 and 3, with the first being *"Horribly Bad"* and the second *"Extremely Good"*, which evaluates the tapestry in terms of usability and user experience features through 26 items within six main scales which evaluate attractiveness, perspicuity, efficiency, dependability, stimulation and novelty. Each item uses two terms with opposite meanings;

2) five adapted questions from the EGameFlow questionnaire [14], a 5 Likert scale, between 1 and 5, with the first meaning *"Strongly Disagree"* and the second *"Strongly Agree"* to evaluate in terms of user immersion and engagement, with the following sentences:

- EGF_Complexity - I found the tapestry unnecessarily complex.
- EGF_Learnability - I would imagine that most people would learn to use this type of interface.
- EGF_TimePassing - I forgot about time passing while interacting with the installation.
- EGF_Immersion - I become unaware of my surroundings while interacting with the installation.
- EGF_Involvement - I feel viscerally involved during the experience.

3) three questions from the Transportation Scale [35], a 7 Likert scale, between 1 and 7, with the first meaning *"Not at all"* and the second *"Very Much"* to evaluate the narrative flow and user engagement in terms of cognition, emotion and imagination, with the following sentences:

- TS_Cognitive – I was mentally involved in the narrative while interacting with the experience.
- TS_Curiosity – I wanted to learn how the narrative ended.
- TS_Emotional – The narrative affected me emotionally.

At the end, following the post questionnaire, we did a semi-structured interview.

4.2 Demographic Results

Our 26 participants' ages ranged from 18 to 59 years old (Mean=4.27, SD=0.827). The majority of the participants were aged between 21 and 29 years old (see graphic 2 from Figure 5). Fifteen of our participants were male, and eleven were female (see graphic 1 from Figure 5).

4.3 Quantitative Results

The analysis of our quantitative data from the Ocean Knowledge Assessment, User Experience Questionnaire, EGameFlow Questionnaire, and Transportation Scale presented optimistic results.

4.3.1 Ocean Knowledge Assessment. We measure the internal consistency of the content knowledge questionnaires (n=8) with an acceptable results Cronbach's Alpha ($\alpha = 0.716$). We then analysed the data for normality using SPSS through the Shapiro-Wild normality Test, and the normality assumption was met since it is >0.05 (1st Questionnaire: p=0.9770; 2nd Questionnaire: p=0.9639). As such, we conducted a parametric analysis with the Paired Samples T-Test. The analysis of the content knowledge showcases significant positive results when comparing the 1st Questionnaire (*M=62,53, SD= 16.29*) with the 2nd Questionnaire (*M=73.30, SD=11.82*). The difference between means was significant, (*M=10.77 and SD=12.74*), t(26)=4.3, p<.05, two-tailed.

The following image (Figure 6), showcases the results obtained before and after the interaction with the tapestry.

4.3.2 User Experience Questionnaire (UEQ) Results. The mean results for each of the 26 items in the User Experience Questionnaire were obtained (Figure 7). The items are grouped into six dimensions: Attractiveness, task-related aspects (Perspicuity, Efficiency, and Dependability), and non-task-related aspects (Stimulation and Novelty). All the dimensions gathered positive results. Attractiveness, Perspecuity, Efficiency, Stimulation, and Novelty presented higher results, meaning the participants enjoyed the interactive tapestry, found the interface easy to use, completed the tasks, felt excited and motivated to engage with it, and perceived it as innovative and creative, captivating their interest. The Dependability scale, while positive, had lower results, meaning that the participants moderately felt in control of the experience.

The UEQ results demonstrate that the participants' emotional reaction to the experience was significant, as the Attractiveness dimension received the highest scores (see Figure 8 and Figure 9). The results also indicate that participants were engaged and had fun while interacting with the tapestry. Finally, while the Pragmatic Quality aspects (see Figure 9), received lower scores, they were still positive, as users successfully achieved the goals proposed within the experience.

4.3.3 EGameFlow Results. The EGameFlow questionnaire presented the following results for each question:

Question	Mean (M)	Standard Deviation (SD)
EGF_Involvement	4.73	0.533
EGF_TimePassing	4.62	0.697
EGF_Immersion	4.58	0.697
EGF_Learnability	4.50	0.812
EGF_Complexity	1.19	0.402

Table 1: Mean and Standard Deviation of EGameFlow Results

The EGameFlow results indicated that the participant's involvement with the experience was high, as demonstrated by the users' behaviour when interacting with the tapestry (EGF_Involvement: *M=4.73, SD=0.533*). The user engagement also proved to be very high, manifested by the user's expressions when interacting with the tapestry. They showed to be focused and attentive with the different elements presented in the tapestry and the opportunity to interact with them. (EGF_TimePassing: *M=4.62,SD=0.697*). The sense of immersion was high, as the participants were unaware of their surroundings and lost track of time. This indicates strong engagement through enjoyment and a desire to listen and interact further (EGF_Immersion: *M=4.58, SD=0.697*). This was supported by the qualitative data, where the participants expressed that they did not notice the time passing, and that they had time to feel the textures and give attention to the tapestry details. The complexity dimension gathered a very low score (EGF_Complexity: *M=1.19,SD=0.402*), and the interaction learnability was high (EGF_Learnability: *M=4.50, SD=0.812*), meaning the interactive tapestry instructions were perceived as clear and easy to follow, expressed by the successful conclusion of the experience and the lack of necessity for help, showcasing these interface instructions and affordances were effective.

4.3.4 Transportation Scale Results. The Transportation Scale presented the following results for each question:

These three elements, besides helping to analyse the involvement of the users with the narrative, can also promote learning [38]. The adequacy of the information is simple enough to understand the story (TS_Cognitive= *M=6.50, SD= 0.707*), maintaining the users' curiosity (TS_Curiosity: *M= 6.19, SD= 1.132*) and leading them to continue through emotional involvement (TS_Emotional= *M=4.65, SD=1.810*).

Question	Mean (M)	Standard Deviation (SD)
TS_Cognitive	6.50	0.707
TS_Curiosity	6.19	1.132
TS_Emotional	4.65	1.810

Table 2: Mean and Standard Deviation of Transportation Scale Results

4.3.5 Interaction with the Interactive Tapestry Duration. While we controlled the time to analyse how long the participants' interaction with the interactive tapestry took, this was not possible for one participant, as such, we removed the participant from this chart,

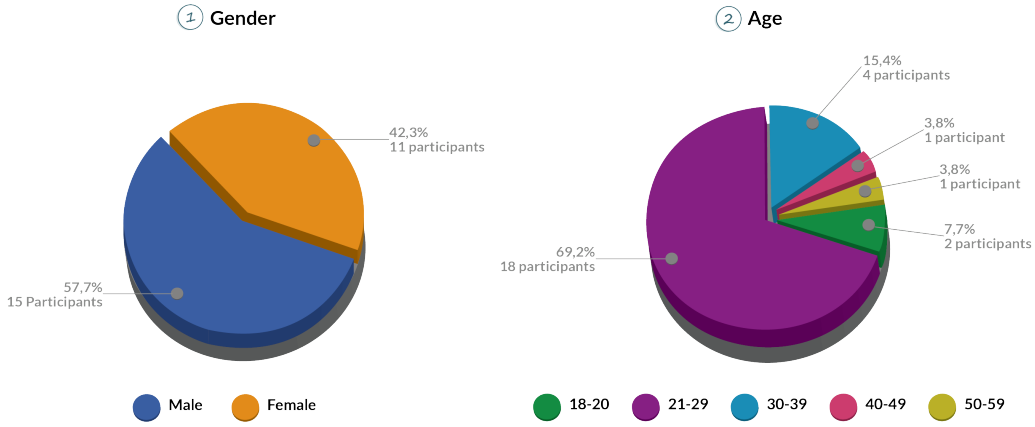

Figure 5: Demographic Results: 1) Participants Gender; 2) Participants Age

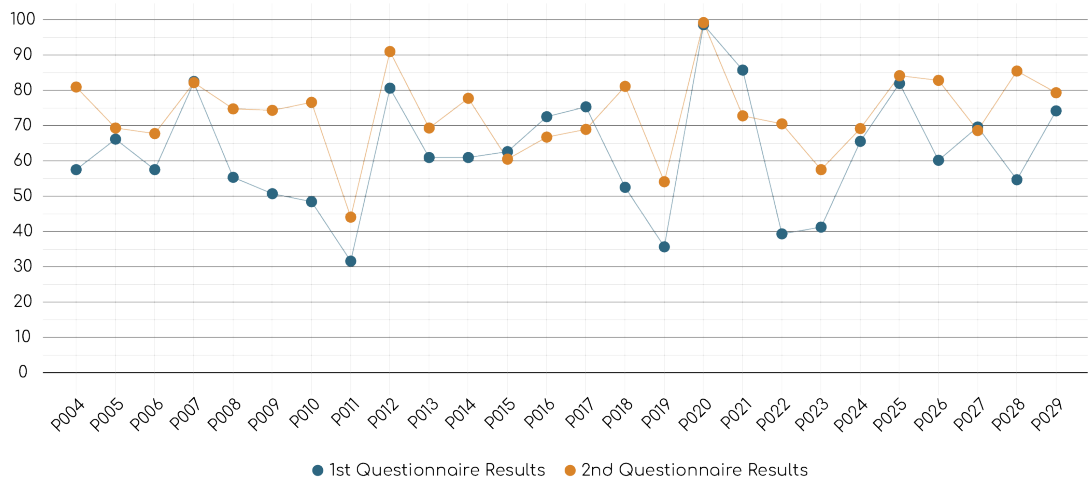

Figure 6: Before and After results of the Questionnaire about the ocean

Figure 10, to have more coherent results. So, within 25 of the 26 participants, the *M= 7.59* and *SD=1.32*. Even though everyone concluded the experience, we noticed most participants took more time than expected, especially the ones who took more than 11 minutes.

4.4 Qualitative Results

The analysis of our qualitative data from the observation notes and the semi-structured interview presented positive significant insights.

We observed that some participants were confused at the beginning about how to interact with the interactive tapestry, however, they were all able to start and conclude the experience with success.

4.4.1 Interaction Areas Results. We observed that the participants used different types of touch, according to the element they interacted with. For example, some were careful placing the characters onto the tapestry than others who placed it with more strength. We also noticed that some participants interactions had a more explorative touch, touching the tapestry and feeling the textures for a longer period of time. Some participants expressed being engaged by the narrative, sometimes speaking with the characters, sometimes laughing at what was being said, and other times demonstrating feelings such as angriness and preoccupation due to the events. During the interaction, we detected some interaction areas where some participants had more difficulties, such as in interactions 2, 3, 6 and 10, as shown in Figure11.

In Interaction 2 (placement of the whale on the left side of the tapestry), some participants had difficulties with recognising the whale's shape (see Figure 11, number 2) since it was their first time doing this type of interaction, and the shape was somehow different to the usual whale silhouette, a more simplified figure. However, we observed that after this interaction, they understood how to place the characters in the following similar interactions.

In Interaction 3 (touching the sound waves coming from the whale), some participants had some issues with the timing, touching before the previous audio finish; others used a single-tap touch, similar to a touchscreen interaction, and others did not understand what the visual representations of the sound waves were.

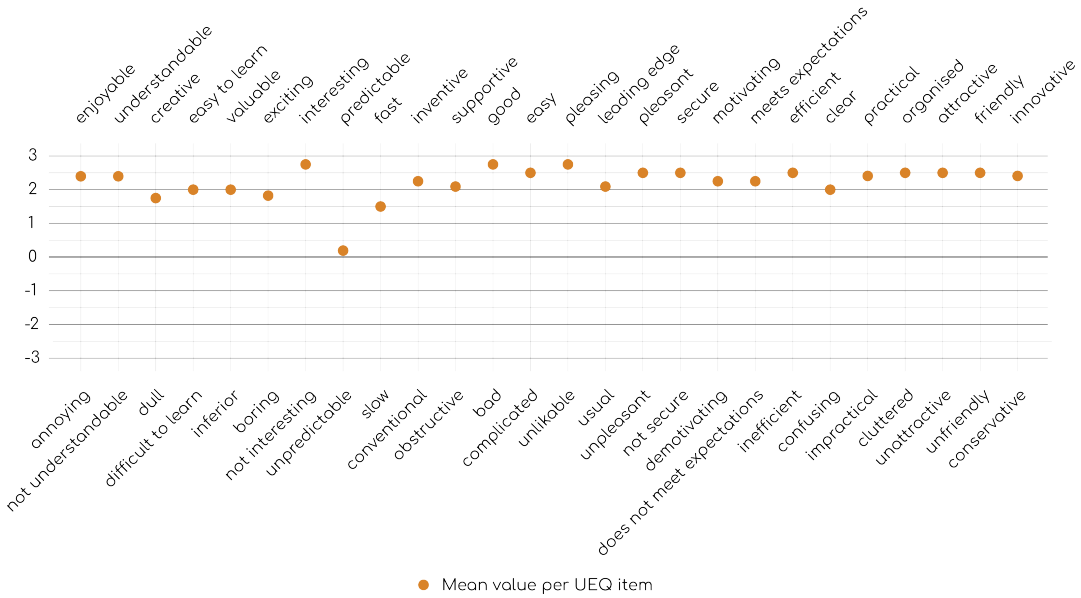

Figure 7: UEQ results for each of the 26 items

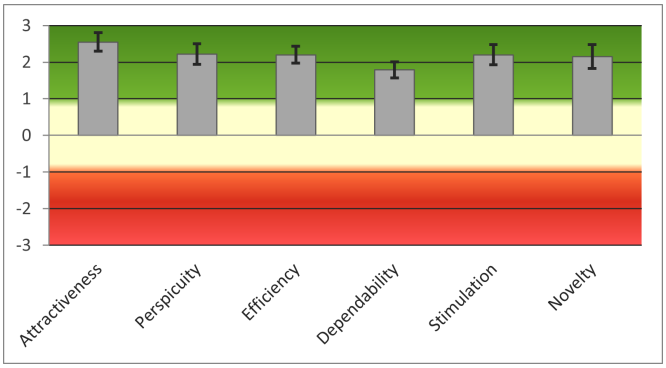

Figure 8: *UEQ Six Dimensions Mean Results*

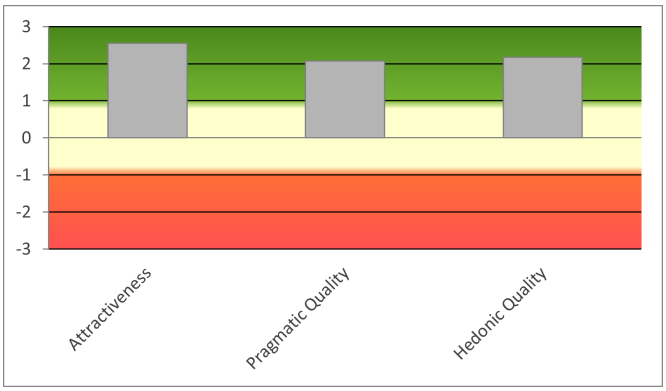

Figure 9: *UEQ Pragmatic and Hedonic Quality Mean Results*

In interaction 6 (touching the green ocean invading the blue ocean), some participants did not understand the instructions given by audio because of the clownfish velocity speech.

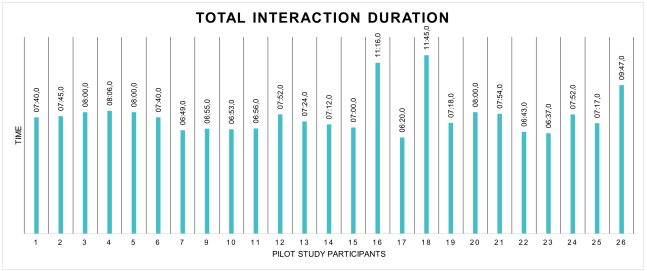

Figure 10: Duration of the interaction with the interactive tapestry

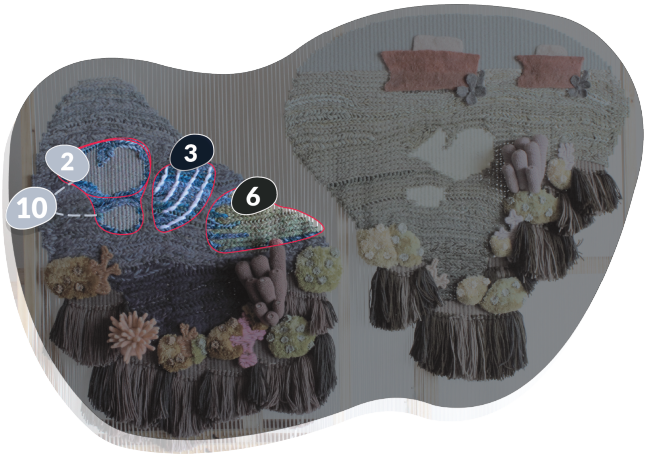

Figure 11: Most problematic interaction areas

In interaction 10 (bring the characters back to the right tapestry), some participants found some technical difficulties with displaying the sound – this sometimes happened because of the interaction timing, sometimes because some participants brought both characters at the same time, and sometimes because the sensor was not detecting the user touch.

4.4.2 Semi-structured Interview Results. We grouped our data around the main topics we discussed with the participants. However, not every participant discussed every topic. Our thematic analysis showcased the following results:

Interactive Tapestry Concept: The participants' understanding of the concept of the interactive tapestry was as follows: sixteen participants identified noise pollution as the theme, e.g. P007: *"It is about the noise pollution in the oceans, disorienting and harming marine life"*. Five saw it as general marine pollution, and sixteen mentioned the impact of human actions, e.g. P006: *"I was able to see the differences between the world with the human intervention and without the human intervention"*. Others highlighted specific features, two noted different phases of the ocean, two learned about marine species, and two mentioned the tapestry raised awareness.

Notorious Differences between left and right tapestries: The participants acknowledge that they understood the difference between tapestries and worlds through colours, textures and tapestry elements. Most of the participants linked vivid colours to a healthy ocean and unsaturated tones to pollution, e.g. P004: *"The colour is greener, it looks more polluted"*. Seven participants noticed conceptual elements, focusing on ships and absent marine life on the unhealthy side of the ocean. Eight recognised differences in sound, e.g. P023: *"One was calmer and more appropriate for marine life, and the other was noisy and disturbing"*.

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. Most of the participants found the tapestry features were cohesive, e.g. P019: *"Yes, I think yes! I liked it a lot and the fact of being a tapestry... I never saw anything like this. The thing I found interesting here, is the way you showcased this approach with the tapestry, with the sound, and with its power of touch."*. They also included suggestions for clearer instructions for the interaction and enhancing the audio feedback to guide the users.

Power of Decision: We asked some of our participants if they felt they had any power of decision, and the answers varied on decision-making. Some participants felt limited power, and others felt their actions were essential to the narrative, e.g. P015: *"I was actually making something happen, I was not just touching to reproduce audios."*, and P019: *"I was the medium for the story to continue."*. Some participants also suggested including more autonomy and non-linear paths for the narrative.

Duration: The participants' opinions about the duration of the experience were mixed, some manifested as being sufficient, e.g. P011: *"The duration was good because it gave me the steps and I had enough time to feel the texture, give attention to the details, the sound..."*. Some forget about time passing, e.g. P022: *"I didn't even notice, I liked the experience so much that I didn't notice"*. Others felt it was too short, especially during narrative moments.

Emotions, Feelings and Reactions: We noticed that our participants felt emotions, feelings and reactions. The experience evoked diverse emotions, from joy and empathy to sadness and worry, e.g. P007: *"I was relieved that the men turned the ships off so the whale could guide herself back home again."*. Some participants felt the immersion was strong due to multisensory elements. The study might have blocked some emotions, e.g. P026: *"I think I didn't feel emotions, but maybe it is because of the context we are doing this study."*.

Target Audience: Some participants suggested the tapestry might suit all ages, e.g. P008: *"I think any child or adult would pedagogically benefit from this project"*.

Changes Suggestions: We gathered several suggestions for the tapestry components. The participants said we should add more feedback focused on enhancing the interaction, the narrative depth, and technical elements, e.g.P018 *"Maybe increase the interactivity with the user"*. Some participants told us we could include more dynamic audio, e.g. P006: *"I think I would increase the volume to raise the user discomfort."*, interactive "Easter eggs", e.g. P024: *"You have there a lot of elements that don't have any interaction... I mean... I haven't tried, but it could have other interactions, an easter egg, something hidden"*, and realistic visual. Others suggested adding autonomy to the narrative flow. Several participants also mentioned the clownfish's speech was too fast, e.g. P019: *"The clownfish should speak slightly slower."*.

5 Discussion

This study aimed to evaluate our interactive tapestry as a storytelling tool and assess its impact on audience engagement and usability, fostering non-formal learning and raising awareness of marine noise pollution and its harmful effects on marine ecosystems.

The findings suggest positive results in terms of audience engagement. In the eGameFlow and Transportation Scale questionnaires, many participants answered they felt viscerally involved during the experience, forgot about time passing while interacting with it, and became unaware of their surroundings. Most participants demonstrated feeling engaged and immersed in the experience, where several components of the interactive tapestry contributed to these sensations, particularly the use of the tapestry elements with its textures. The narrative and its characters brought a layer of empathy connection with the participants and gave them the agency to the continuity of the story. Some participants also expressed their desire to be able to interact with the tapestry more time, and most of them lost the notion of time while interacting. We believe these features contributed to the learning outcome since the more the participants engaged with the tapestry through its elements, the more portions of the narrative they heard, and so they were able to learn more.

The UEQ demonstrated promising results related to usability. However, we noticed minor usability challenging situations from observation notes and interviews concerning sensor areas or audio instructions that were not clear enough, where we see space for improvement. Relatively to the sensor areas, we noticed that the participants used different types of touch, and we detected some

fear of touching the artwork – as the usual understanding of experiencing an artwork in a museum is by observing and we are not usually permitted to use touch – and single-tap touch, similar to a touchscreen touch – maybe because we are so used to interact with mobile devices nowadays.

Regarding the impact of interacting with this piece, some participants felt they were emotionally affected and expressed their feelings through facial, body and oral expressions during the interaction. Furthermore, some participants said they felt emotions like empathy, compassion, sadness, anxiety, stress and angriness during the interview. Some others also reflected on human intervention in the oceans, demonstrating their understanding of the impact on the marine environment. Moreover, the results of the Ocean Knowledge Assessment questionnaire reflected a positive impact on the participants' knowledge.

In the following subsections, we address our research questions and reflect upon the limitations and future work related to our research.

5.1 RQ1: How do design elements of an interactive tapestry impact user interaction and intuitive navigation?

The design elements of an interactive tapestry significantly influence user interaction and intuitive navigation by seamlessly combining visual cues, audio instructions, and material affordances. These elements were carefully developed to guide users through the narrative while accommodating diverse interaction types, such as explorative touch and single-tap approaches.

Visual and material affordances worked together to enhance user interaction and create an intuitive experience with the interactive tapestry. Visual indicators, such as the character silhouettes and designated placement zones, played a central role in guiding users, reducing ambiguity, and ensuring accessibility. Meanwhile, the physical design of the tapestry and its characters invited tactile engagement, encouraging users to manipulate and place the characters intuitively. Together, these visual and tactile affordances elements support a seamless and immersive interaction, allowing users to navigate the narrative naturally, as Letters to José [9–11] does.

The audio instructions complemented the affordances by providing step-by-step guidance. The pairing of these modalities ensured that participants understood when and where to interact, fostering a smoother navigation experience. This combination was effective for participants to be guided and to provide more details supporting the tapestry's visual affordances.

Our design choices collectively facilitated intuitive navigation. While interacting with the tapestry, the participants contributed to the narrative by placing the characters on the tapestry, which made them active participants in the experience and gave them a sense of competence. During the study, some participants quickly identified where to place characters, such as the whale, using the tapestry's affordances. Even minimal instructions were sufficient, as users relied on the combination of visual, auditory, and tactile cues to guide their actions. Observations, combined with the UEQ and EGameFlow, demonstrated that the participants gradually became familiar with the recurring interaction patterns. They recognised the low complexity of the tapestry interactions, which boosted their confidence and allowed them to complete tasks independently.

However, the study also revealed areas for improvement. Some participants struggled with identifying specific zones, such as distinguishing the green ocean from the blue ocean, due to limited visual clarity or insufficient audio cues. Improving these affordances by enhancing visual contrasts or adjusting character dialogues, since the participants reflected that the audio velocity sometimes does not make the speech clear, could support user understanding and interaction.

Additionally, the diverse interaction styles observed in the study highlighted the need for flexibility in design. While some participants used tactile exploration, others treated the tapestry like a touchscreen, using single taps that sometimes delayed the responses, particularly with the sound waves sensors. Interaction duration was influenced by factors such as the time required to process audio instructions or explore textures, underlining the importance of accommodating unpredictable behaviours in future iterations.

In conclusion, the combination of visual, auditory, and material affordances in the interactive tapestry enhanced user interaction by supporting intuitive navigation and engaging diverse interaction styles. These findings provide valuable insights for refining future designs and ensuring a more inclusive and user-friendly experience.

5.2 RQ2: Can an interactive tangible tapestry promote awareness of marine noise pollution?

Although we expected positive results, the optimistic results led us to believe that the use of tangible interfaces can engage the user through a seamless thought interface, which discusses a critical biodiversity issue almost without the users noticing they are acquiring knowledge in a non-formal way.

Narrative elements fostered curiosity and emotional involvement, driving participants to continue exploring the tapestry. Results from the Transportation Scale revealed that users remained engaged as they wanted to understand how the story unfolded, leading to increased interaction and a greater understanding of marine noise pollution. The questionnaires about the ocean made before and after the interaction with the tapestry presented a significant result, while the interviews confirmed that the participants understood the tapestry's message and expressed concern for marine life, which proved the use of this type of ancestral technique, such as Barragão [4] and Kehayoglou [23] artworks, allied with technology, such as Guridi et al. [16], and Echeverri et al. [9, 11] approaches, was effective in promoting this environmental message. Moreover, for some participants, this experience would be pedagogically valuable for everyone.

However, emotional responses varied. This may be attributed to the challenge of simultaneously learning the interface, completing tasks, and following the narrative, which could reduce emotional engagement initially. Nevertheless, many participants reported feeling immersed, highlighting the success of the combination of tactile, visual, and narrative elements.

The study also identified areas for improvement. We could make the experience more personalised, interactive, and emotionally

resonant by enhancing user agency and engagement while incorporating more autonomy and non-linear narrative paths.

In conclusion, the interactive tapestry proved to be an effective tool for raising awareness of marine noise pollution. By merging tactile interaction, narrative, and emotional engagement, it facilitated significant learning and reflection. With the improvements we mentioned, the tapestry has the potential to deliver an even more impactful and personalised experience.

5.3 RQ3: How can we optimise the integration of conductive materials within traditional tapestry techniques to ensure reliable performance and user satisfaction?

We used the Bare Conductive Touch Board technology [6] to support our weaving tapestry, enabling capacitive sensors that provided audio feedback upon touch. While every participant finished the experience, the seamless integration of this technology with traditional tapestry techniques presented several challenges.

This interface is made of wool, a material that can create several textures, volumes and shapes. It is also capable of creating visual affordances and encouraging touch. This was supported by the results of Attractiveness from UEQ, and participant feedback during the interviews. However, the wool in an interactive tapestry also presents a durability challenge since it allows people to interact with it by touch. Over time, it might damage the materials, especially in the interaction areas. We can eventually replace the damaged wool when it is damaged, but it would require equal or at least similar materials and careful craft to preserve the integrity of the interactive piece.

We integrated conductive threads and fibre with the wool, and it permitted seamless interaction with the multimedia content, forming a unique, creative and unified piece, as participants told us. However, the use of conductive thread for some types of sensors, such as sound waves (represented by wool lines), needs improvements since, during the study, we detected some technical challenges due to the type of touch executed. To solve this, we might need to improve the sensor area with more conductive material or increase the sensor sensibility. Some participants noted that they did not fully utilise the tapestry's tactile elements. Addressing this result, we can also try to make the user understand that the tapestry allows a more explorative touch by changing the audio, asking to not be afraid of touching the tapestry and appealing for a more sensitive touch. The study mentioned that there was no mechanism to deal with users who abandoned the experience mid-interaction. We can address this challenge by improving the programming of the microcontroller and adding a speech telling the user to place the characters in the plinth to then start the experience.

In conclusion, optimising the integration of conductive materials within traditional tapestry techniques requires addressing technical and usability challenges. Enhancing the sensors' sensibility and materials' durability, combined with the user learning outcome, would ensure reliable functionality and a satisfying interactive experience.

5.4 Lessons Learned

With the process we followed so far with Tapest[o]ry, we can offer some early valuable lessons for interactive storytelling design beyond its specific implementation. By sharing these lessons, we hope to help other designers create more effective and engaging TUI interactive storytelling experiences.

Integrate interactive technology to enhance, not overshadow, the core medium: Tapest[o]ry successfully embeds capacitive sensor technology within the tapestry without compromising its aesthetic or tactile qualities. In our approach, the technology activates and progresses the narrative, driven by user interaction with the textile. We learned the importance of thoughtful integration, ensuring that technology amplifies the medium's strengths and supports the storytelling goal, demonstrated in the interview results, where we had participants impressed by the idea of using textiles with technology and the power of touch to interact with the tapestry.

Leverage the inherent storytelling potential and cultural associations of traditional media: Tapest[o]ry demonstrates the power of using a medium with a rich history of storytelling, like a tapestry, as the foundation of an interactive system. The tactile and visual qualities of weaving can evoke a sense of connection and contemplation, which designers should consider and try to leverage more of the inherent cultural meanings and sensory affordances that traditional mediums can have to enhance engagement and narrative resonance.

Structuring TUI narratives with clear cues and feedback to guide user agency: The narrative in Tapest[o]ry follows a traditional structure with interaction points that drive the story forward. Audio instructions and the user's actions of physically manipulating elements provide clear feedback. This indicates that compelling interactive storytelling requires a balance between user agency and clear guidance to ensure intuitive navigation and a sense of accomplishment. Even though we had planned clear guidance for our audience, we still found that some participants had difficulties understanding some of the speech. We also acknowledged that we could still change the narrator's speech to ask for more texture exploration.

Utilising physical affordances of the Tapestry to facilitate interaction: With the evaluation, we found that despite some initial confusion, participants were generally able to learn how to interact with the tapestry and complete the experience. We believe that the tapestry elements, such as character silhouettes and designated areas, acted as visual and material affordances that guided user interaction. The act of placing characters and touch the different tapestry elements becomes an intuitive way to progress the narrative.

5.5 Limitations and Future Work

While the experience was designed for a controlled study context, allowing for seamless restarts between users, it does not currently account for situations where a user abandons the experience in the middle of it. In a museum context, a real-life situation, a user could leave the characters misplaced on the tapestry. To address this, it is necessary to develop a mechanism to alert the next user to return the characters to their starting position on the plinth. This could

include additional visual clues, such as character names near their silhouettes and an audio-guided timer reminding users to reset the characters.

The tapestry, made primarily with wool, might get damaged over time due to frequent user interaction. The areas of the highest touch frequency, such as the interaction zones, are especially vulnerable to damage. Replacing damaged materials periodically is a potential solution. Still, if we remove the tapestry from the loom, we can risk losing the warp tension, which might influence the executability of replacing the damaged materials. In future iterations, we should explore ways to replace materials without compromising the structural integrity of the tapestry.

OUr evaluation involved a small number of participants, which restricts the generalisability of our findings. Although the study provided valuable insights, a larger, more diverse participant group could offer more data to validate our results and showcase clearer interaction patterns.

Many study participants felt they did not fully utilise the tapestry's tactile elements, and through the observation, we noticed the type of touch influenced the interaction efficiency. To address this, we plan to improve the design flexibility, where we can use the introductory message from the narrator to encourage users to touch, feel and explore the different elements and textures without hesitation.

Based on the study feedback, we plan to enhance the sensor areas, particularly the sound waves, by increasing their sensitivity with additional conductive material. We also aim to improve the audio tracks by reducing the speech velocity of the clownfish, improving clarity and instructions due to the participants' difficulty in understanding.

In the future, we could include branching storylines with multiple possible endings to explore the full potential of interactive narratives. This would give users greater autonomy and create a more engaging and personalised experience.

We designed the tapestry for single-user interaction, where only one person interacts with the interactive pieces and hears the narrative through headphones. In a real-world environment, we might encounter multi-user scenarios where more than one person might want to interact simultaneously, which we have not considered for the controlled study this paper analyses. We think the solution might be to remove the headphones and reproduce the audio through speakers, where everyone close to the tapestry hears the narrative and can collaborate with the interaction. The use of speakers for multi-user interaction might bring other challenges, such as: where the tapestry is placed – we would choose a quiet place; and how the multiple users will interact simultaneously with the interactive tapestry since it will only detect one touch at a time to follow the narrative - in the case of having two users, each one can play with a character, however in the case of having more than two users, they must decide between them who does the interactions.

By addressing these limitations and incorporating these improvements, we aim to refine the interactive tapestry into a robust, durable, engaging embodied interface capable of being presented to larger audiences in real-world settings. These enhancements will ensure the tapestry delivers an enriched user experience while effectively conveying its narrative and message.

6 Conclusion

This paper presents the evaluation of an interactive tapestry as a TUI for storytelling. The tapestry not only revives the storytelling capabilities of traditional weaving techniques but also raises awareness of critical anthropogenic issues, particularly marine noise pollution. By integrating capacitive technology, such as conductive threads and fibres connected to the Bare Conductive Touch Board, the tapestry provides an immersive sensory experience. This technological integration allowed us to create a narrative-driven interface where users play an active role in unveiling the story, emphasising the impact of marine noise pollution through sound and tactile interactions.

Furthermore, our user evaluations highlight the potential of interactive storytelling TUIs to foster empathy and awareness. Participants actively engaged with the tactile and auditory elements of the tapestry, reflecting on its message and demonstrating the medium's capacity to emotionally connect with audiences. These results highlight the potential of interactive tapestries to not only convey narratives but also inspire action on pressing environmental issues.

We aim at creating a framework 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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References

[1] Mia Aasbakken. 2012. Evaluating User Experiences from Interactive Art Installations.
[2] AWI. [n. d.]. Ocean Noise. https://awionline.org/content/ocean-noise
[3] Rashmita Bardalai and Jenny Underwood. 2022. SensAE – A Tool to Explore Material-Touch-Emotions. *Journal of Textile Design Research and Practice* 10, 2 (2022), 141–163. https://doi.org/10.1080/20511787.2022.2100170
[4] Vanessa Barragão. [n. d.]. Vanessa Barragão. https://vanessabarragao.com/about
[5] Zafer Bilda. 2006. Evaluating Audience Experience with Interactive Art. *Interactive Art Journal* (2006). Accessed: 2024-01-17.
[6] Bare Conductive. [n. d.]. Bare Conductive. https://www.bareconductive.com/ Accessed: 2024-01-23.
[7] Marine Stewardship Council. [n. d.]. Marine Biodiversity. https://www.msc.org/en-au/what-we-are-doing/oceans-at-risk/marine-biodiversity
[8] Chris Crawford. 2013. *Chris Crawford on Interactive Storytelling* (2nd ed.). New Riders.
[9] Daniel Echeverri and Huaxin Wei. 2020. Exploring the Experience with Tangible Interactive Narrative: Authoring and Evaluation of Letters to José. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* 12497 (2020), 15–29. https://doi.org/10.1007/978-3-030-62516-0_2
[10] Daniel Echeverri and Huaxin Wei. 2020. Letters to José: A Design Case for Building Tangible Interactive Narratives. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* 12497 LNCS (2020), 15–29. https://doi.org/10.1007/978-3-030-62516-0_2
[11] Daniel Echeverri and Huaxin Wei. 2021. Designing Physical Artifacts for Tangible Narratives: Lessons Learned from Letters to José. *TEI 2021 - Proceedings of the*

15th International Conference on Tangible, Embedded, and Embodied Interaction (2 2021). https://doi.org/10.1145/3430524.3446070

[12] Lucy Ellis. [n. d.]. The Impacts of Noise Pollution in the Ocean | Earth.Org. https://earth.org/noise-pollution-in-the-ocean/

[13] Freshmind. 2024. Interactive Art: The Growing Trend of Audience Participation in Modern Artworks. https://freshmindmag.com/2024/09/03/interactive-art-the-growing-trend-of-audience-participation-in-modern-artworks/ Accessed: 2024-01-17.

[14] Fong Ling Fu, Rong Chang Su, and Sheng Chin Yu. 2009. EGameFlow: A scale to measure learners' enjoyment of e-learning games. *Computers and Education* 52, 1 (1 2009), 101–112. https://doi.org/10.1016/J.COMPEDU.2008.07.004

[15] Jawad Golzar and Omid Tajik. 2022. Convenience Sampling. *IJELS* N/A, 2 (2022), 1.

[16] Sofia Guridi, Tamara Vicencio, and Rodrigo Gajardo. 2021. Arpilleras Parlantes: Designing Educational Material for the Creation of Interactive Textile Art Based on a Traditional Chilean Craft. *TEI 2021 - Proceedings of the 15th International Conference on Tangible, Embedded, and Embodied Interaction* (2 2021). https://doi.org/10.1145/3430524.3440657

[17] Daniel Harley, Jean Ho Chu, Jamie Kwan, and Ali Mazalek. 2016. Towards a framework for tangible narratives. *TEI 2016 - Proceedings of the 10th Anniversary Conference on Tangible Embedded and Embodied Interaction* (2 2016), 62–69. https://doi.org/10.1145/2839462.2839471

[18] Kristina Höök, Phoebe Sengers, and Gerd Andersson. 2003. Sense and sensibility. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (4 2003), 241–248. https://doi.org/10.1145/642611.642654

[19] Hiroshi Ishii and Brygg Ullmer. 1997. Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms. *PAPERS CHI* 97 (1997), 22–27.

[20] Keisha Jacobs. 2022. Weaving Watery Worlds: An Interview with Vanessa Barragão. https://www.artshelp.com/vanessa-barragao/

[21] Christopher Johnson, Ryan Reisinger, Daniel M. Palacios, Ari S. Friedlaender, Alex Zerbini, Andy Willson, Melanie Lancaster, Jessica Battle, Alistair Graham, Aurelie Cosandey-Godin, Théa Jacob, Fernando Felix, Emily Grilly, Umair Shahid, Nathalie Houtman, Amalia Alberini, Yacqueline Montecinos, Eduardo Najera, and Shaleyla Kelez. 2022. *Protecting Blue Corridors - Challenges and solutions for migratory whales navigating national and international seas.* Technical Report. WWF. https://doi.org/10.5281/ZENODO.6196131

[22] Judit Just. [n. d.]. About 1 — jujujust. https://www.jujujust.com/about. Accessed: 2025-01-17.

[23] Alexandra Kehayoglou. [n. d.]. BIOGRAPHY - Alexandra Kehayoglou. https://alexandrakehayoglou.com/BIOGRAPHY. Accessed: 2025-01-17.

[24] Mary Maddocks. 2020. *Weaving: A modern guide to creating 17 woven accessories for your handmade home.* Hardie Grant Publishing, London. 1–160 pages.

[25] Mary Lou Maher and Lina Lee. 2017. Designing for Gesture and Tangible Interaction. *Synthesis Lectures on Human-Centered Informatics* 10, 2 (3 2017), i–111. https://doi.org/10.2200/S00758ED1V01Y201702HCI036

[26] Martin Johnson Dominika Majewska. 2022. Formal, non-formal, and informal learning: What are they, and how can we research them? https://files.eric.ed.gov/fulltext/ED626005.pdf

[27] Douglas J Mccauley. 2023. The future of whales in our Anthropocene ocean Slowing down ships presents one of several promising avenues for reducing harm to whales in an increasingly noisy and busy ocean. *Science Advances* (2023). https://doi.org/10.1126/sciadv.adf2987

[28] Fabio Morreale and Antonella De Angeli. 2015. Evaluating visitor experiences with interactive art. *ACM International Conference Proceeding Series* 28 (9 2015), 50–57. https://doi.org/10.1145/2808435.2808440

[29] Ann J. Morrison, Peta Mitchell, and Margot Brereton. 2007. The lens of ludic engagement: Evaluating participation in interactive art installations. *Proceedings of the ACM International Multimedia Conference and Exhibition* (2007), 509–512. https://doi.org/10.1145/1291233.1291358

[30] Felicia Murray. [n. d.]. About – Felicia Murray. https://www.feliciajmurray.com/pages/about. Accessed: 2025-01-17.

[31] UEQ Online. 2023. User Experience Questionnaire (UEQ). https://www.ueq-online.org/

[32] Irene Posch. 2021. Crafting Stories: Smart and Electronic Textile Craftsmanship for Interactive Books. *TEI 2021 - Proceedings of the 15th International Conference on Tangible, Embedded, and Embodied Interaction* (2 2021). https://doi.org/10.1145/3430524.3446076

[33] Quizizz. 2024. Human Impact on Ocean Ecosystems. https://quizizz.com/admin/quiz/5c191876cea813001a7129db/human-impact-on-ocean-ecosystems

[34] Quizizz. 2024. Marine Pollution REVIEW. https://quizizz.com/admin/quiz/5f21d730e022d0001cfcf555/marine-pollution-review

[35] Enhanced Reader. 2025. Running head: Transportation Scale.

[36] Maria Roussou, Akrivi Katifori, Irene Kaklopoulou, Katerina Servi, and Dimitra Petousi. 2024. Engaging Teens Through Playful Tangible Interaction with Emotive Stories in Museums. *Interactions* 31, 3 (May-June 2024). https://interactions.acm.org/archive/view/may-june-2024/engaging-teens-through-playful-tangible-interaction-with-emotive-stories-in-museums

[37] Laura Santos, Mara Dionisio, and Pedro Campos. 2024. TapeStory: Exploring the Storytelling Potential of Interactive Tapestries. In *Proceedings of the 16th Conference on Creativity & Cognition* (Chicago, IL, USA) *(C&C '24)*. Association for Computing Machinery, New York, NY, USA, 686–699. https://doi.org/10.1145/3635636.3656211

[38] Nicola S. Schutte. 2020. The Impact of Virtual Reality on Curiosity and Other Positive Characteristics. *International Journal of Human-Computer Interaction* 36(7) (10 2020), 661–668. https://doi.org/10.1080/10447318.2019.1676520

[39] Jouni Smed, Tomi Suovuo, Natasha Skult, and Petter Skult. 2021. Handbook on interactive storytelling. *Handbook on Interactive Storytelling* (7 2021), 1–200. https://doi.org/10.1002/9781119688167

[40] Anne Sullivan and Emily K. Johnson. 2019. BeadED Adventures: Crafting STEM Learning. In *Proceedings of the Thirteenth International Conference on Tangible, Embedded, and Embodied Interaction* (Tempe, Arizona, USA) *(TEI '19)*. Association for Computing Machinery, New York, NY, USA, 351–358. https://doi.org/10.1145/3294109.3300997

[41] Embellished Talk. [n. d.]. Juju Just Do It – Embellished Talk. https://embellishedtalk.com/juju-just/

[42] Bokumoni Akonga Jonas Theodore. 2024. The Nature of Matter: An Inherent Element in the Interpretation of a Work of Art (Three-Dimensional). *Art and Design Review* 12, 4 (2024), 340–369. https://doi.org/10.4236/adr.2024.124024

[43] V&A. [n. d.]. V&A · What Is Tapestry? https://www.vam.ac.uk/articles/what-is-tapestry

[44] Writers.com. 2023. Freytag's Pyramid: Definition, Examples, and How to Use This Dramatic Structure in Your Writing. https://writers.com/freytags-pyramid

[45] Fangmeng Zeng, Guanghua Wang, Jie Qiao, Qicai Wang, Meiqin Wu, Xiangsong Zeng, and Xinghua Hong. 2024. Modeling the relationship between fabric textures and the evoked emotions through different sensory perceptions. *Journal of Engineered Fibers and Fabrics* 19 (2024), 15589250241248761.