Lessons Learned on Engaging Teenage Visitors in Museums with Story-Based and Game-Based Strategies

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While museums are designed to engage and interest various audiences, teenagers are often a neglected segment. Without digital interactivity, it is challenging for a museum to remain exciting and relevant to a young, tech-savvy audience. Games can benefit museums by fostering positive attitudes towards museum spaces and creating more joyful destinations to promote meaningful informal learning combined with entertainment. We developed a dual gamified mobile experience targeted at teenagers, for the Natural History Museum of Funchal, Portugal: a story-based strategy (*Memories of Carvalhal's Palace – Turning Point)* and a game-based strategy (*Memories of Carvalhal's Palace – Haunted Encounters*). These strategies were studied in depth with 159 teenagers (15-19 years old) to understand how gamified strategies might enhance their user experience in a museum. On the one hand, game-based strategies, in which game mechanics predominate, can catch a visitor's attention by displaying challenging questions that promote competition. On the other hand, story-based strategies, in which storytelling is prominent, can promote an emotional connection with the museum and exhibits and facilitate awareness of historical facts by including an engaging plot with high-quality media and tightly edited stories. This article reports on lessons learned that museum experience designers and curators can use in designing enjoyable, interactive experiences for teenage visitors.

CCS CONCEPTS • Human-centered computing • Human computer interaction (HCI) • HCI design and evaluation methods

Additional Keywords and Phrases: Storytelling, Gamification, Game-Based, Story-Based, Gameplay, Museum Experience, Augmented Reality, 3D Objects

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1 INTRODUCTION

As museums become increasingly sites of school field trips, tourism trips, and even family trips, the design of social visiting becomes more relevant [14,64]. However, according to Falk [35], the so-called 'one size fits all' principle does not apply to visitor experiences. Moreover, not all museums can afford to design exciting experiences for all kinds of demographics [22]. As a result, the teenage audience is often left out, sitting somewhere in the middle between children and adults. Yet, this user group has a valuable set of contributions to make; additionally, as reported by Fitton et al. [39], they are in a better position for combining both child and adult perspectives. Notably, teenagers seem to be a difficult audience to engage, and at the same time, a neglected typology of visitors for cultural heritage sites. 'Generation Z' (who are today 13-18 years old) is seen mainly as entirely different from previous generations, particularly regarding their beliefs and behaviours [14,70] – they are constantly connected to technology and constitute a complex demographic that is changing faster than any other generation before them. This generation is identified as an audience group that is often excluded from a museum's curatorial strategies [20,69]; as a consequence, they appear to be generally disinterested in what museums might offer.

Recently, several studies [2,22,34,37,66] have questioned the museum's mission to educate, versus the visitors' desire for entertainment. In fact, while museum professionals focus more on educational values, audiences appreciate museums for their entertainment aspects [13-15]. Traditionally, museums have provided the public with access to cultural, scientific, and historical exhibits as well as informed commentary and research. However, the museum experience should be more than knowledge transfer [50]. Therefore, museums are increasingly adopting technologies to support more engaged learning and immersive entertainment. Edutainment offers entertainment designed to be educational [48]; this concept can act as an excellent gateway to education. In particular, with today's teenage fast-paced information consumption and preference for gamification strategies [22,50], edutainment is successful in entertaining people simultaneously as they are engaged in thinking, reflecting and learning. Whatever the primary goal of the institution, a two-way strategy that balances entertainment with education could help museums strengthen their mission as well as fulfil audience needs. At the same time, gamification and playful interaction [30] afforded by the wide spread of mobile personal devices (in museum settings) offer opportunities to attract young visitors [5], enabling a closer relationship with a museum's stories and exhibits. Blanchard and Cheska [7] state that play is widely perceived as an accepted form of learning. Several scholars also agree that most of the popular games are 'untapped educational resources' [41] which might provide 'a glimpse of how we might create new and more powerful ways to learn' [67]. Games and narrative elements are proven to improve engagement, motivation, and learning within edutainment environments [46].

Starting from the presented motivation, this article articulates a set of lessons we learned on utilizing digital story-based and game-based strategies to enhance the museum experience for teenagers and create awareness about the museum's focus and message. To address this broad topic, we have situated our study in a specific context: high-school students visiting the Natural History Museum of Funchal, Portugal. In total, 159 teenagers aged 15-19 visited this museum guided by a story-based or game-based strategy embodied in a custom-made mobile application. The lessons learned from this study could be used as a starting point in the development of mobile museum experiences targeted at teenagers (15-19 years old).

2 RELATED WORK

While the use of mobile devices to enhance and enrich museum visits has a long history [3,11,40,44,49,51,52,65], the idea that entertainment and gaming can play an equal role alongside the learning mission of a museum is a more recent approach. Museums are recognized as a fertile arena for the gamification challenge [62]. Moreover, Sung and colleagues [68] found that problem-solving on a mobile device amplified visitors' motivation for learning due to their need to search for details in order to correctly answer the proposed challenges. Stories and games can boost the learning goals of the museum while enhancing the playful aspects of the visit. Previous research demonstrates that storytelling and game-based approaches benefit museums by promoting joyful and exciting experiences, which have the potential to support meaningful learning [33,45]. Moreover, games and storytelling are two of the most used techniques to engage young and adult audiences as museum visitors [29,47,54,71]. In this section, we review gamified approaches, which focus on treasure hunting and storytelling enhanced by gamification.

2.1 Treasure hunting

Mystery and treasure hunting [9,31] as well as problem-solving tasks have the potential to engage, entertain, and scaffold visitors' learning through museum contexts [1,27,57,62,68]. In the past few decades, a mass of game-based museum programs has been designed for different media platforms and visitor types, such as those reported below.

Ghosts of a Chance [4] was implemented at the Smithsonian American Art Museum (SAAM). The community was encouraged to participate using the internet, phone, email, and face-to-face interaction. This game involved a sequence of clues and puzzles and was well received by both adults and teenagers. Although it was not educational, it encouraged visitors to think about art in a fun and social way. This research was valuable for us in supporting our intent to educate the audience informally.

MuseUs [28] is a pervasive serious game, developed as a mobile application, for the learning of cultural heritage. By scanning a QR code near an art piece, museum visitors could achieve two things. Firstly, they could access more information about that specific piece and secondly, they could match the exhibit to a virtual frame in the virtual space of the mobile application. The evaluation of the mobile application shows benefits in the context of children's learning, who were prompted to consider the exhibits from diverse viewpoints. Moreover, it highlighted immersion as an essential aspect of the game success. The study also highlights the importance of limiting the search to a single achievable area; otherwise, the user could find the challenge to be burdensome. This suggestion was incorporated into the design of our gamified strategies such that participants could quickly achieve the areas to go further in the experience.

More recently, *Ocean Game* [25] explores a natural history museum's content through proximity beacons and visual cues. When children and teenagers (9-11 years old) are near the icon/sticker representing the artefact, the system will signal the presence of content. In this instance, a short animation appears on the smartphone screen, suggesting that key information regarding the animal/artefact is present. The game ends when all the species are collected and quizzes, one per species, are answered. This study highlights that *Ocean Game* is more engaging and enjoyable than a traditional guided tour. However, guided tours did support rich social interaction among children and, therefore, excitement, as they were touring the museum in a group while the place-based game aspect of the game stimulated several specific behaviours in the children — namely, competition and collection.

2.2 Storytelling and gamification

Much has been done and said about adventures in museums, from blockbuster films (*Night at the Museum* and its sequels) to books (Eco's *Foucault's Pendulum* [32], and Brown's *The Da Vinci Code* [8]). Cabrera and colleagues [9] built an interactive museum guide called *Mystery in the Museum*, at historical/cultural museums, which allowed students to play and perform tasks related to certain exhibits. In this activity, groups of students collaborate to solve a mystery inside the museum, interacting through mobile devices. Each group plays a role in the story and receives different pieces of story relevant information through the mobile device. At the end of the visit, they have to join and discuss the different clues they have collected, rebuilding the story and trying to solve the mystery. In this experiment, some students (13-19 years old) lost interest in the interactive guide due to the complexity of the tasks, while others switched the focus from the displayed exhibits to the handheld computers. This study warned us about the hindrances of complexity in tasks performed for fun. *Mystery in the Museum* stimulates children's imagination through storytelling. The plot of this game-based approach involves some puzzles that relate to the exhibits. The most typical examples include scrambled images of specific exhibits and verses from manuscripts of the museum. The authors argued that they might have built a tour led by the digital device instead of the exhibits displayed in the museum. That is because the players interacted more with the device than with the exhibits in order to solve the given quests. This insight played a role in the design of our gamified strategies, more precisely the game-based strategy, as the visitors have to carefully look at the exhibits on the shelf in order to correctly answer a question on the smartphone.

Ghost Detector [53] is a story-driven and educational location-based museum experience for children that utilizes beacons to locate the content. In this interactive story, ghosts of various museum exhibits appear on the screen of the young

visitors' mobile device and challenge children to find the exhibits that the ghosts represent. During evaluations of this experience, children were observed running through the corridors, paying attention to the feedback on the smartphone as well as the exhibits surrounding them. This study highlights the fact that the introduction of the ubiquitous ghost story undoubtedly influenced the level of excitement and engagement with the museum premises.

Intrigue at the Museum [71] is a plot-driven mobile game for children structured around exploration and task performance. It is a single-player game whose plot invites visitors to search for a thief in the museum among a set of virtual characters. Clues are given to the players, and they solve riddles after scanning tags deployed in the building. Following a constructivist approach, the game allows children to explore the museum environment freely, according to their interests and agenda. This paper shows that location-based games might represent a relevant learning resource in a museum setting while promoting engagement and entertainment.

3 DUAL MOBILE EXPERIENCE

The *Memories of Carvalhal's Palace* (MoCP) dual experience (story-based and game-based strategies) was designed based on the findings and requirements identified in previous studies [12,13,17,18,21] and the specific context of the Natural History Museum of Funchal (NHMF). The MoCP experiences aimed at fostering emotional connection and promoting awareness about the museum's environment and taxidermy exhibits, in particular drawing attention to certain endangered species. Hence, based on the same museum premises and exhibits, two interaction strategies were designed, implementing several requirements (Table 1).

Figure 1: Example of markers attached to the museum for unlocking digital content on the game-based strategy (first and second images) and the story-based strategy (third image).

The two strategies use both game and storytelling techniques but to different degrees. One is game-based, centred on game mechanics and featuring storytelling as a background – *Memories of Carvalhal's Palace – Haunted Encounters* (MoCP-HE); this strategy follows a non-linear approach, where once the game has started, the elements can be encountered in any specific order. The other approach is story-based, centred on the unfolding of a dramatic plot complemented with some game elements – *Memories of Carvalhal's Palace – Turning Point* (MoCP-TP); this second strategy follows a linear approach, in which the story events must be experienced in a specific sequential order. We studied and compared the different strategies in order to better understand teenagers' preference towards museum experiences. Both strategies make it possible for teenagers to share their memories (game score and selfies) on social media channels. The mechanics of both rely on finding Augmented Reality (AR) markers near specific exhibits that indicate the presence of digital content to be unlocked (Figure 1). Below, we describe the rationale related to both mobile strategies, along with their differences.

Table 1: Design requirements implemented in the MoCP dual experience, from our previous work [21].

Topic	Requirement adopted
Making memories	- Share the experience on social media channels - Make memories by taking *photos and selfies* with and without AR effects
Usability	- Simple *usage* of the mobile guide - The user interface and overall designs should be *appealing*
Exploration	- See different exhibits when taking *different digital tours* - Guide the visitor through the museum by using a *map* to check out points of interest and locations - Prompt the discovery of *unknown rooms and places* inside the museum
Scientific info	- Receive *information about the exhibits* through descriptive texts and plain images, access to their natural sounds and videos in their natural habitats - Display *curiosities and information about the museum* through general videos and descriptive information
Digital interaction	- Utilize *digital technologies* to augment the exhibits' physical information, such as *3D models*, Augmented Reality - Use of *location-aware technologies* for unlocking information
Storytelling	- Utilize *story-based* narratives to guide the experience - Base the story on an *adventurous journey*: teenagers tend to take on a leading role for themselves - Link an *emotional journey* within the museum: the exhibits that are part of this plot must be helped in some way by the users to generate an emotional impact
Gameplay	- Utilize *clues* in text and/or image format that can be combined with puzzles and questionnaires to challenge the teenage visitor - Search for and discover exhibits through *treasure hunts* and be provided with information about the same - Challenge teenagers' knowledge about the exhibits through *quizzes* - Accomplish of in-game *achievements* through receiving points, unlocking information and increasing the level of the game - Utilize *collection* of pieces (of exhibits or stories) to complete a puzzle and form a bigger picture

3.1 Story-based strategy (MoCP-TP)

With the story-based strategy – linear approach, users are encouraged to sequentially visit specific physical locations of the museum to unlock the story plot and solve the mystery behind it (Figure 2). The game aspect relies on a simple mechanic: finding 16 AR markers near specific exhibits that indicate the presence of story content and unlocking story fragments that progress the plot. The story is divided into four acts, containing 16 audio-visual fragments in total. With the aid of a map, the mobile application guides the users from the garden of medicinal and aromatic plants of the museum to continue the mobile experience inside the museum.

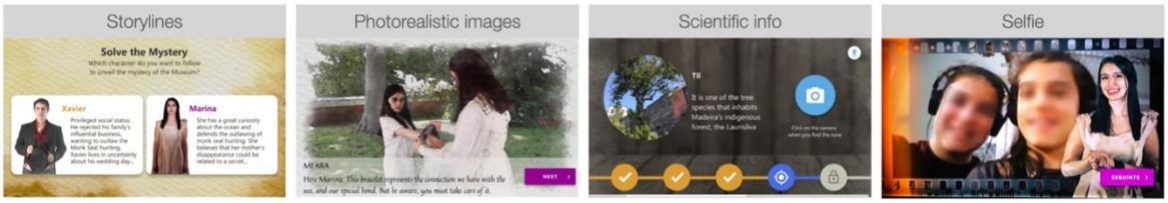

Figure 2: Screenshots of the story-based strategy: (i) when the users are invited to choose one of the characters to follow the story from their point of view; (ii) photorealistic rendition of a story fragment; (iii) clue given to the user to help them find content in the museum's garden; (iv) resulting selfie that the user takes with the character at the end of the experience.

Upon starting the mobile application, the audience is presented with a tutorial about its use. The story is narrated through photorealistic images of the characters accompanied by dialogues rendered as voice-over audio and text. The user is asked to choose one of the two main storylines and follow the story from the point of one of the two main characters – the couple Xavier and Marina. Depending on which of the two they decide to follow, the events will proceed along a different point of view and involve different animal species in the museum, revealing additional scientific facts about the Madeira Island's fauna and flora. To unlock the story plot sequence, the mobile application will guide the user through various sections of the museum, where they can find AR markers, each of which unlocks a new story fragment and is connected to a species of plant or animal. Markers can be scanned using the mobile app.

Upon completing the story, the user can restart the experience, follow the other character's point of view, and complete their understanding of the story's unfolding events while interacting with different exhibits. Care has been taken to not repeat content in the two storylines. Furthermore, users are rewarded, in the end, with the possibility of taking a selfie picture with the virtual image of the story character whose point of view they have just experienced and sharing it on social media (Figure 2, section iv). The MoCP-TP was already showcased as a demo [23].

3.2 Game-based strategy (MoCP-HE)

With the game-based strategy – non-linear approach, users learn that the museum was once the residence of a noble Madeiran family (Figure 3). According to the game backstory, some mysterious forces are at play, disturbing the museum spaces.

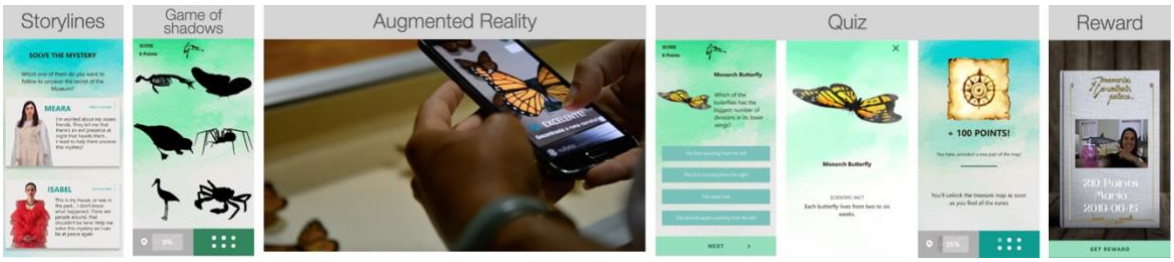

Figure 3: Screenshots of the game-based strategy: (i) the two main characters who call the player to take action; (ii) the interface of the game of shadows; (iii) the 3D model of the butterfly displayed as Augmented Reality; (iv) question related to the exhibit, scientific facts about the species, and a piece of the map unlocked; (v) the selfie photograph with Isabel's malignant spirit, which the user encountered; it will be emailed to Maria – the user – along with her game score.

The game is connected to the story plot. Besides exploiting the same story world and family saga, we wanted to encourage players to access the story and vice versa and discover and learn more about the museum content. For this

reason, none of the content of the game repeats the content touched in the story. When the mobile application is launched, a tutorial is displayed. The users are instructed to take a selfie which will work as their avatar in the game, after which they meet two fictional characters, Meara and Isabel, respectively Marina and Xavier's mothers, who ask the players for help. Depending on which character the players choose to help, two different museum tours and game endings are delivered. Meara leads the player to explore the marine species collection of the museum, while Isabel leads them to get to know the terrestrial fauna. To uncover the truth about the haunting of the museum, the players engage in a game of shadows, in which they must match six museum exhibits with the silhouettes proposed by the mobile application, one at a time. Unique markers contradistinguish the species that are part of the game. By identifying the correct species from its shadow, the players unlock a corresponding AR three-dimensional (3D) model from the marker. They can explore it in detail by manipulating the 3D model on the mobile application. They can rotate the model in all directions, complementing the knowledge and experience gained from observing the exemplar on the glass shelves. After the marker and the corresponding AR 3D model are captured, the mobile application asks the audience to take a quiz about the animal on the shelf. This question requires the user to look closely at the exhibited species, as the question is related to an aspect of its physical details. After answering the question correctly or incorrectly, the audience is presented with a text reporting several scientific facts about the animal.

For every completed interaction, from finding the silhouettes' corresponding animal to receiving the scientific information, the audience is rewarded with a piece of a puzzle representing a map. Once completed, the map will guide the players to a hidden location, the scientific library of the museum (almost unknown to the museum's visitors), and ask them to find a physical treasure chest. A visual marker identifies the chest, hidden in the library shelves. Scanning the marker will present the players with one of the two potentially different endings, depending on which character they decided to help at the beginning.

Regardless of whom they have been helping, all players receive a reward for finishing their quest. They receive a digital postcard containing their selfie with the specific ghost or malignant spirit they encountered and their game score, which they can share on social media. The MoCP-HC was also already showcased as a demo [26,55].

3.3 Study

We first conducted a preliminary study with 16 teenagers to evaluate the feasibility of the research and improve upon the study design before the performance of full-scale testing in the museum: we tested the flow of the study, the duration of the experience, and the questionnaires. Then, we tested both story-based and game-based strategies with a large sample of teenagers inside the selected museum – the NHMF – to determine whether those requirements from [21] worked when applied to a real-life scenario. The main study was conducted with 159 teenagers (77 females, 82 males) from several schools in Funchal, Madeira Island, aged between 15-19 years old. Each one was coded from P1 to P159 (meaning Participant #1 to Participant #159) to guarantee the anonymity of the data. Participation in visiting the museum and being part of the study was voluntary. Parents and legal tutors signed consent forms on behalf of their children to participate in the study. The evaluation took part during a school field trip to the museum with their class and teacher. Teachers showed interest in showing new modes of mobile museum interaction to their pupils. We scheduled a two-hour time slot for each class of 15/25 students and organized them into groups of two people. We delivered one smartphone to each group to experience one strategy only – game-based or story-based. During the experiment, these smartphones recorded their conversations, which we later transcribed to find patterns of attitudes describing the mobile museum tour and experience. From these recordings, we came to understand how teenagers perceive the impact of using two different mobile strategies (results were published in [24]). Upon completing the mobile tour, the participants were briefly interviewed in their groups

to give us qualitative feedback on what they liked the most and the least about the whole exhibition empowered by a mobile application. Then they were instructed to fill out questionnaires regarding their experience. This article analyses the results of the interviews conducted and the post-questionnaires filled out.

4 ANALYSIS

A total of 67 teenagers tested the story-based strategy and 92 teenagers tested the game-based strategy. The interviews were transcribed and coded through thematic analysis using NVivo 12, and the results of the post-questionnaires were inserted into SPSS to apply statistical tests and discover if there was any significant difference between both apps. We did not split the data by gender as, at this stage, we wanted to test only the differences between the two strategies (story-based vs. game-based) and not between groups of teenagers (male vs. female).

4.1 Interviews

Each of the topics covered during the interview was analysed for each mobile experience. In total, 351 references were split into three topics as shown in Figure 4: (i) gamified strategies (rich features, poor features, improvements); (ii) specific for story-based strategies (rich features, poor features, improvements); (iii) specific for game-based strategies (rich features, poor features, improvements). Below, we report the codes, in *italics*, related to each topic along with their descriptions and examples of transcripts illustrating what teenagers said.

Figure 4: Graphs showing the differences in percentages regarding the references coded for each topic.

4.1.1Rich features for gamified strategies

Exploration of the museum (65 references) describes exploration as a very positive feature. Participants liked the idea of walking freely and searching for the AR markers, locating the exhibits in the museum through the clues given, as well as

visiting hidden places, such as several minor exhibition rooms and the library. Users mentioned that thanks to the exploratory activity, some exhibits which were not part of the mobile experience caught the users' attention.

- P146 & P149: *'We had the opportunity to try to understand what a museum is.'*
- P97 & P98: *'I liked having to go looking for the various places that the app asked for, and I found it interesting.'*
- P67 & P70: *'What I liked the most was... was looking for the symbols to see the 3D.'*
- P153 & P154: *'I saw an animal, but this was not part of the application. It was a very big fish, I was also curious to see it.'*

Technology (38 references) informs us that participants regarded the technology of the mobile application as a positive feature. Participants stated that the museum supported by technology is no longer 'boring'. They thought the whole experience was innovative, as they were trying out an app never experienced in a museum. They liked the graphics of the mobile application. Participants enjoyed the interaction through AR in checking the 3D models of the species: They could rotate and check the model carefully. The mobile application was very organized, telling the user where they should go, and the species were near each other, not far away. Participants liked that the museum provided the smartphones with the app already installed rather than having to download it on their smartphones.

- P41 & P43: *'It's better than having a guide show us what it [exhibit] is... It's a more interactive way of visiting the museum, it's not boring.'*
- P113 & P114: *'I liked the images, the overall graphic design.'*
- P93 & P112: *'It was all organized about where we had to go, and it was like, more or less close. The species were here, they were not on the second floor or the fourth floor. One was here and another one was there. It wasn't too far away.'*

Encounter of museum exhibits (30 references) regards how participants liked to check the exhibits along the mobile tour. Participants liked seeing the taxidermied species exhibited in their real shapes, some of which they had never seen.

- P93 & P112: *'The sharks… I liked seeing the species in full size.'*
- P99 & P100: *'I liked some species for their size, some for their shape and everything...'*
- P117 & P126: *'I was able to get closer to the species and see them.'*

4.1.2Poor features for gamified strategies

Difficult to encounter exhibits (8 references) describes the difficulties encountered throughout the mobile tour. Some exhibits were difficult to encounter because they were small (such as the seahorse and plants in the garden), which required visitors to take different paths to encounter them.

- P26 & P27: *'Discovering the seahorse… was small, difficult.'*
- P73 & P74: *'The treasure chest... I couldn't find it!'*
- P145 & P147: *'The garden was more challenging... it had more species...'*

4.1.3Improvements in gamified strategies

Increase the challenge (28 references) informs us that the tour should be improved by adding questions to augment the difficulties of the challenges and competition among users: The experience should provide more quizzes and increase the number of species to encounter so that the experience lasts longer. The experience should embrace more rooms and not be concentrated in only one room or floor.

- P108 & P110: *'More questions and stuff like that, it's more challenging.'*
- P105 & P106: *'More species to find.'*

- P33 & P34: *'Maybe not having everything just on the same floor. It's just that if they are on different floors, it would be a little more complicated and this would be nice.'*

Provide more information (7 references) describes the fact that the mobile application should give more information to the visitor about the species: Habitats and tips on preserving the endangered species.

- P68 & P69: *'Click and see their habitat, have more information about them.'*
- P72 & P76: *'Or maybe even show an image... I don'' know, anything I was looking at could warn me to not harm the animals, or something like that.'*
- P102 & P103: *'I might like to have a little more information about some species, some more details.'*

4.1.4Rich features specific to story-based strategies

Narrative and voices (16 references) informs us that participants liked the fact that they played an active role in the mobile story by going to different spaces and species to unravel the story. They liked the drama of the plot and the audio narration of the story. The voices showed emotion and were funny.

- P108 & P110: *'I liked the writing of the dialogue.'*
- P146 & P159: *'I also enjoyed hearing a little bit of the museum's history.'*
- P195 & P106: *'The voices, the intonation, the theatre!'*
- P131 & P132: *'Then we started to appreciate the story. The way they talk is funny.'*

4.1.5Poor features specific to story-based strategies

Story extension (45 references) describes the story as being too long. Although participants mentioned that they enjoyed the story, they also said that it was too long and 'boring', as the users should be in a specific location to listen to a lot of stories in a row. Also, the mobile application had too much text to read.

- P153 & P156: *'The amount… that we had to listen...'*
- P113 & P114: *'I think the story should have been simpler... it was too long.'*
- P105 & P106: *'They spoke a lot.'*

Map (4 references) informs us that the map in the garden was difficult to understand, as was the transition from the garden to the museum.

- P93 & P112: *'The map, it was kind of complicated to know where we were.'*
- P99 & P100: *'No, it was to go up to the second floor. We thought we still had to go higher to another floor.'*
- P102 & P103: *'That part was where we all got mixed up, we thought we had to go upstairs or down.'*

Slow dialogue (1 reference) relates to the mobile tour as not appealing. The slow dialogue affected the user's interest in the plot. They found it hard to keep their attention focused and lost track of the drama.

- P131 & P132: *'Because they spoke very slowly.'*

4.1.6Improvements specific for story-based strategies

Shorten the story (13 references) informs us about how the story should be improved by: (i) shortening the story in each point of interest where users need to stop to listen to it; (ii) increasing the speed of the voices of the characters; (iii) removing the text as users were listening to the audio.

- P101 & P104: *'Maybe shorten the story.'*
- P113 & P114: *'I would remove the text, we were only listening and not reading.'*
- P132: *'Just make the story a little faster or put it all in a row.'*

4.1.7Rich features specific to game-based strategies

Learning (18 references) describes the tour as a way of learning new content. Participants liked learning and discovering several facts about the museum's species – facts that, if they were told about in another way, it would be difficult for them to learn. Also, the act of looking at the taxidermied species in search of the right answer allowed users to learn specific facts.

- P42 & P50: *'This app is good because it helps us to memorize the details that, if they were said by a human guide, would not stay in our heads.'*
- P56 & P57: *'Yes, we have to look, and we have to reflect. If it was a person talking, it wouldn't be so clear...'*
- P12 & P13: *'I liked to know curiosities about the animals.'*

Challenge (16 references) describes the competition and treasure hunt as interesting. The users liked having the map and getting to the library in search of the treasure to unlock the mystery and discover ghosts.

- P39 & P40: *'Trying to find out the answers to the questions.'*
- P16 & P17: *'Walking through the library, finding the mystery.'*
- P56 & P48: *'My favourite part was finding the treasure chest.'*

Team group (1 reference) describes the fact that participants liked working in pairs and supporting each other throughout the tour.

- P33 & P34: *'It was working as a team, it was cool.'*

4.1.8Poor features specific to game-based strategies

Not engaging (11 references) relates some features as not engaging: (i) the search for just six animals was too easy, as were the questions; (ii) participants found the mobile application childish: the 3D model of the exhibits and the ghosts encountered at the end; (iii) the 3D could be more realistic and show more details inside the species (their organs); (iv) the treasure chest was too easy to find, not well hidden.

- P85 & P89: *'What's more annoying is... there were six, weren't they? It should be a little bit more, to explore even more.'*
- P7 & P8: *'When we found the chest, then a lady appeared [the ghost], she started making noises there. For our age, this is kind of weird.'*
- P24 & P25: *'The treasure chest was poorly hidden.'*
- P62 & P65: *'I think when we see the animal in 3D we should see more things, like what it looks like inside, its organs…'*

Library as not appealing (9 references) describes the library as a place not appealing to go to. It was 'boring' to look for the treasure chest because it was inside a library; participants did not like the place itself, nor did they like the act of searching for a treasure chest. Also, the treasure chest was hard to find in the library; this was a difficult part because participants did not have a clue about where the treasure chest would be hidden.

- P86 & P88: *'It was a bit boring being in the library, trying to find... I don't like libraries.'*
- P72 & P76: *'It was a boring bit… Walking around looking for a chest.'*
- P87 & P89: *'The treasure chest had to be searched for inside a library… it was too much.'*

Game focus (7 references) describes the mobile experience focusing just on a game and not the museum. Participants paid more attention to the species the game proposed than to the museum itself. The mobile application showed only some specific animals and places, not prompting the user to find/discover the rest of the museum. Users were very focused on playing the game and were paying more attention to the 3D models than to the exhibited species themselves.

- P1 & P2: *'It doesn't lead us to see the other species, basically. We don't even look properly at the other animals because we are so focused on the game.'*
- P41 & P43: *'We paid more attention to what was proposed to us in the game.'*
- P14 & P15: *'Imagine, walking alone to see what is there, rather than looking for a specific animal. I would always be looking down instead of looking at the species exhibited in the museum...'*

Game extension (6 references) describes the experience of the game as fast, or too fast. Participants would have liked to have more challenges to solve, they mentioned having too few animals to find, and, thus, the game ended up being too short.

- P3 & P29: *'It was a quick bit.'*
- P16 & P17: *'Maybe too fast.'*
- P37 & P38: *'I think there were few species to search for…'*

Possibility of failure (4 references) describes the moments when participants failed, which seems mostly connected to lack of support or adequate information from the app. Understandably, participants did not like losing points throughout the tour by answering the questions incorrectly or asking for help in the mobile application while not knowing that would have cost them points.

- P24 & P25: *'Fail the questions...'*
- P44 & P51: *'Losing 45 points for help we didn't know about.'*
- P59 & P60: *'Yes... If we get the question wrong, we lose all the points.'*

Difficult questions (3 references) informs us that some questions were difficult to answer as the player did not feel like they had adequate information or support to answer them.

- P35 & P36: *'There was a question that we didn't really know the answer to, and we had no way of knowing. We didn't have the information.'*
- P68 & P69: *'Yes, there were animals [seahorse] that we didn't know what they were like...'*
- P71 & P77: *'The questions... because I didn't understand one word and then it was difficult to answer...'*

Taking selfies (2 references) describes the fact that participants did not like to take a selfie at the beginning, without understanding the experience first.

- P1: *'The selfie...'*
- P2: *'I didn't like taking the selfie.'*

4.1.9Improvements specific for game-based strategies

Challenge (14 references) informs us about how the tour should be improved by (i) increasing the overall difficulty of the experience for it to be more challenging; (ii) adapting the mobile application for different age groups: For teenagers, it should be more difficult/challenging, as teenagers like to visit the exhibits that interest them; if they like something specific, they go to search for it; (iii) hiding markers better to increase the challenge.

- P80 & P81: *'And the species must be more hidden or be smaller for the game to become more difficult.'*
- P83 & P84: *'I would add more animals to discover.'*
- P7 & P8: *'For us teenagers, we usually come just to see, or we like something and look for it. You should adapt it to different ages. And for older people, as they walk slower, but they like it... they spend a lot of time watching. They usually like to read more.'*

Different tours (5 references) describes more options for tours. More characters should be added with different routes at the beginning so that the visitors have more choices to check at the museum. Because the museum has a lot of variety in terms of natural history, the game could be arranged according to different species such as: mammals, birds, plants.

- P80 & P81: *'You could add more characters.'*
- P24 & P25: *'You could split the content through the various areas. From what I saw, there are plants, birds... And the app just shows us marine fish. That's just a little bit of what exists here...'*
- P10 & P11: *'Add more characters, there were only two: Meara and Isabel.'*

4.2 Questionnaires

Statistical methods were applied to the results of the post-questionnaires to determine if there was any statistical difference between the two experiences: the Museum Experience Scale [59] that assessed *engagement*, *knowledge*, *meaningful experience*, and *emotional connection*, the Multimedia Guide Scale [59] that assessed *general usability*, *learning and control* of the guide, and *quality of interaction* of the guide, and the Game Experience Questionnaire [63] that assessed *positive experience*, *negative experience*, *tiredness*, and *returning to reality*.

We used the Kolmogorov-Smirnov test to assess the normality of the data. All the variables listed above in italics were not normally distributed ($p<0.005$); hence, we applied non-parametric tests – *Mann-Whitney Test*. Through this analysis, we found two significant results. In the results reported below, the Mean is greater than the Mdn (median). This is common for a distribution that is skewed to the right: bunched up towards the left and with a 'tail' stretching towards the right.

Emotional Connection levels are greater in the story-based strategy (Mdn=3.80; Mean=90.57) than in the game-based strategy (Mdn=3.40; Mean=72.30). This difference is significant, U=2373.500, p=0.13, r=-0.20.

Tiredness levels are greater in the story-based strategy (Mdn=0.00; Mean=92.62) than in the game-based strategy (Mdn=0.00; Mean=70.81). This difference is significant, U=2236.500, p=0.000, r=-0.31.

In other words, teenagers felt more emotional connection but also more tired with the story-based strategy than with the game-based strategy.

5 DISCUSSION

Both mobile stories and mobile games can promote teenagers' positive experiences when visiting a museum. Teenagers described the interaction with technology in both experiences as attractive because it engaged them in learning scientific facts while exploring the museum. In both strategies, they heightened challenges and competition among themselves as positive features. In general, teenagers did not enjoy challenges that were too easy to solve or species and places that were difficult to encounter; nevertheless, they would have liked to have more animals to look for and answer quizzes about, and more support in finding them. Those who experienced the story-based strategy indicated that the story guiding them throughout the tour was interesting and emotionally charged but took too long to unfold, and the dialogues were too slow. This finding suggests that the story played a significant role in guiding their museum tour. In summary, both strategies engaged teenagers; they were emotionally involved but impatient, eager to be challenged and competitive. Moreover, teenagers lamented being very focused on the game and the mobile devices, and not enough on the museum as a whole. Incorrectly answering the quizzes was also a negative point of the experience. For the story-based strategy, they reported that the map was difficult to understand especially when they had to orient themselves in the garden of the museum and feeling stuck when listening to the long dialogues and reading the text. On the other hand, those who experienced the game-based approach indicated that the museum should offer a wider variety of tours from which to choose, that there should be more quizzes, and that the challenges should cover all of the exhibits. The markers should be positioned with more care,

so to be more visible. Participants believed that shortening the story would make it more appealing, while those who engaged with the game said that they would increase the element of competition. In addition, teenagers felt more emotionally connected to the story-based strategy due to its plot and characters; they also felt fatigued by the story rather than by the game. The first part of the story-based strategy, which took place in the garden, was more time-consuming, while in the game-based strategy, the teenagers were actively searching for the exhibits only indoors. Those who experienced the game-based strategy appreciated the opportunity to learn from the challenges as a team. In contrast, those who experienced the story-based strategy cherished the emotional involvement with the characters in the story but did not mention any learning or challenges related to the exhibits. This finding suggests that story-based strategies can help teenage visitors engage with a poignant message and historical recounts if approached through character and narrative transportation storytelling features. On the other hand, game-based strategies through quizzes and game mechanics can help teenage visitors learn and develop an awareness of scientific facts related to the museum and its exhibits.

6 LESSONS LEARNED

Based on the thematic analysis of the teenagers' post-interviews and the results of the post-questionnaires, we reflected on some lessons learned that curators and museum interactive experience designers could use when designing gamified strategies for teenage audiences. These lessons are grouped into four topics: (i) *Exploration for learning*; (ii) *Digital interaction*; (iii) *Storytelling*; (iv) *Gameplay*. The rest of this section describes these topics in detail.

6.1 Exploration for learning

Different mobile experience strategies allow users to diversify their encounters with the museum and its exhibits. Teenagers were interested in repeating the museum tour and interacting with other exhibits on separate visits. Mobile strategies increase the exploration of the museum's premises. Non-linear exploration of content, that does not have a predetermined order of fruition, prompt teenagers to explore the museum and stumble on exhibits even if they are not part of the experience. This aspect can generate curiosity to return to the museum and see other parts of it. On the other hand, linear strategies with a sequential and predetermined order of fruition of the content, prompt teenagers to prioritise the exhibits proposed by the experience and allow less free exploration of the museum space.

Gamification supports learning scientific and historical facts related to the museum. At times the museum's building has an important history or artistic value by itself. A gamified strategy, both story- and game-based, can facilitate the approach of teenagers to the scientific, ecological, and historical facts and values that are connected to the museum. These buildings often have rich histories and have been donated by prominent families or society members or were designed, built, or readapted to be museums by renowned architects (e.g., Guggenheim museums in New York, Venice, and Bilbao). A gamified experience should align with the message the museum wants to convey: its exhibits, scientific facts, or even stories related to the building. The game mechanics play an important role in fostering this awareness. If the exhibits are hard to find or are associated with more challenging questions, teenagers seem to enjoy the challenge. However, this feature could overwhelm visitors, as some might not be keen to make decisions or take risks and, thus, feel inadequate. The literature points to harmonizing visitors' experiences by exploring the museum in pairs to support collaborative meaning-making at museums [24,36,61].

Making sure all paths to exhibits are accessible. Museum experience designers can focus on ensuring that all paths leading to the completion of digital tours are not obstructed and that they facilitate the passage of visitors (such as making sure that visitors can open closed doors, if necessary). We suggest that museum experience designers mark the exhibits as part of the gamified experience. A visitor will not view all of the hundreds of exhibits in a museum to find the right one.

Importance of the museum exhibits rather than focusing on the mobile experience only. The exhibits in the museum shelves and glass cases play a unique role in the museum experience. Both the game-based and story-based strategies can play a role to enhance them rather than divert the teenagers focus from them. With the game-based strategy (finding the exhibits and answering quizzes), participants explored the museum and paid attention to the exhibits on the shelves, because they had to answer questions about them.

6.2 Digital interaction

3D models of the exhibits allow for detailed exploration through manipulation of the 3D model on the screen. This promotes engagement among teenagers. Technology can create personal connections between the user and the information content, inspiring teenagers to take a closer look. Many of the exhibits displayed in most museums are locked and untouchable behind a pane of glass; hence, teenagers are interested in interacting with these exhibits through AR 3D models and being able to check out their physical details. The 3D models of the encountered species – reproducing the exhibits in the shelves, and displayed through AR technology – invited a productive indexing activity [43], where the attention of the players shifted back and forth from the exhibit to the model and back. Teenagers highly appreciated the 3D models of the exhibits developed by professional designers. Including imperfections that can be seen in the real exhibit strengthens the feelings of seeing and manipulating what is not otherwise accessible, displayed behind the glass of the museum shelves. Museum curators can partner with schools to curate and enrich the museum's exhibitions to interest and engage students at different stages of their curricula.

Mobile AR and proximity sensing catch the interest of teenagers. Teenagers in our study were fascinated by proximity sensing, visual markers, and AR technologies that unlocked the digital content and enjoyed interacting with it, which they perceived as something novel [14]. Even if teenagers are unfamiliar with the technology, they are excited about it. They will not be scared to learn how to use and interact with it because it is something novel and hence exciting. In the MoCP dual experience, such technologies included image recognition and proximity sensing to unlock digital content and AR 3D technologies to display models of exhibits and allow visitors to see their details.

The mobile strategy should provide clear information and feedback about the location of such exhibits. Most importantly, the map should be easy to understand. Teenagers were interested in checking the map to understand where the exhibits were located in the museum premises. Many technologies today cater for location awareness – such as passive WiFi sensing, Near-Field Communication (NFC), beacons and Bluetooth – if the museum is not equipped for that, then its staff could provide visitors with a clearly legible map to understand the museum building and its room disposition. Otherwise, the risk is that visitors find orienting themselves in the museum burdensome, which can spoil the experience.

Selfies and social media sharing at the end of the experience. Taking selfies and sharing with social media is better done at the end than at the beginning as participants need to warm up to the technology and their tasks in the interaction with the museum. In the story-based strategy, participants were encouraged to take a selfie at the end with a character, and in the game-based strategy, participants were asked to take a selfie at the beginning to be their avatar. While in the first, there were no complaints, in the latter, two participants did not like this interaction. This result tells us that taking selfies has the potential to be relevant but needs to be thoughtfully designed into the flow of the experience. If the technologically mediated interactive experience promotes a fun and engaging tour, teenagers might share their memories of this tour through pictures and selfies on their social media networks [14].

6.3 Storytelling

Story-based strategies can help teenage visitors engage with historical facts and their consequences. Teenagers in our study enjoyed being guided throughout the museum while immersed in a narrative plot, emotionally engaged with the characters and the drama. This is a known effect called narrative transportation [42]. Stories are a common strategy to foster teenagers' engagement in interactive experiences and games (e.g., *Dungeons and Dragons* or the adventure genre). Teenagers are notably interested in being the protagonists of exciting adventures, and museums can harness this to craft experiences that excite a teenage audience while communicating knowledge, familiarising them with ecological messages, or stimulating awareness about endangered ecosystems and species.

Story-based strategies should aim for high-quality media and storytelling. Storytelling for mobile devices has different rules and aesthetics from other media and forms of storytelling. Engaging an audience on the move requires brevity and intimacy in the conversations [56]. With teenagers, this need is accentuated by their impatience combined with curiosity. Tweet-sized text are preferred by teenagers over longer textual explanation or dialogues. Short and frequent content fragments can make the visit more dynamic and better hold the interest of teenage visitors. Some participants in our study skipped through the narrative fragments, pursuing a fast ending of the mobile experience. Moreover, exposing teenagers to short messages and succinct content nuggets invites a broader exploration of the exhibition space encouraging them to move more often to find exhibits that release further stories and scientific facts. Also, from a storytelling perspective, leaving parts of the story to be filled by the player can be exciting, although we did not test this aspect within our story-based strategy. The high-quality of the digital media is essential for teenagers' engagement, as the competition with high-quality games and interactive artefacts they engage with through their mobile devices is increasing. Echoing previous findings [24], museum experience designers could harmonize the experience of visitors who could be classified as passive – those merely consuming the content and performing the actions required by the story-based experience. Interactive elements that require decision-making could be introduced to challenge and gently push them to be more engaged with the exhibition.

6.4 Gameplay

The integration of challenges promotes competition between users, such as searching for something or answering quizzes. Game mechanics lead players through a treasure hunt for content to support learning and engagement [10,22,31]. Collecting is a welcomed strategy for engaging teenagers, as after collecting pieces, they will have a bigger picture at the end [6,22,38,58]. Challenges via quizzes and the ability to earn points promote competition and curiosity among teenage visitors regarding who is best at completing the task [24]. The deployment of clues for finding specific exhibits could enhance teenagers' museum experience and foster a possible increase in knowledge by allowing them to solve these challenges. Competition in a museum is appropriate when visitors explore the museum carefully, learn about the exhibits, and progress through the experience without competing against others. Another issue is the fact that when visitors are too concerned about the technology and competition, they cannot take in the museum content and curatorial message.

Flexible gamified experience tailored to the time at the user's disposal. Our game-based strategy contained only six exhibits; hence, the experience was described negatively as 'too short'. At a closer look, this was seen as a negative aspect because the teenagers had more time at their disposal and they wanted to fill it with playing. Also, clues must be carefully aligned with the logic and purpose of the museum visit. Otherwise, the gamified experience could push teenagers through the exhibits too quickly, which would cause them to focus on finishing the visit rather than enjoying it. A problem arises when visitors switch their focus from the museum experience to the mobile game and start running through the halls in search of the right exhibit without looking at and enjoying the museum itself [25,53,54]. Players could become fascinated

by the screen and fail to observe the physical exhibit in the museum [25,43]. When it comes to managing the visitors' attention between the device and museum space and echoing previous findings in the field [60], mobile strategies should strike a balance between the device and the physical place to allow the user to look at exhibits on the shelves and not only those displayed on the screen of the digital strategy.

7 CONCLUSION

Gamified museum experiences can exploit game and storytelling techniques to different degrees: A game-based strategy centred on challenges can satisfy teenagers' competitive attitudes as explorative drives, and a story-based strategy satisfies more reflective and empathic audiences. However, it can still exploit some game mechanics in pushing teenagers to move around to follow up on the story plot points and explore the museum. Nevertheless, high-quality media and tightly edited stories are paramount for teen engagement.

Lessons learned under the topic "Exploration for learning" aligns with Goodlander [4], *Intrigue at the museum* [71], and *MuseUs* [28]. In accordance with Goodlander [4], we believe that exhibitions supported or combined with gamified mobile approaches can be a fun social experience, assisting teenagers in thinking and learning about the museum collection and the message that the museum wants to communicate. Gamified mobile strategies are an important learning source in a museum while promoting entertainment [28,71]. These strategies encourage teenagers to explore the premises, prompting visitors to look around and occasionally stumble into other exhibits that are not part of the digital experience, looking at them from a different viewpoint and contributing to awareness about a given subject.

Lessons learned under the topic "Digital interaction" aligns with Coenen and colleagues [28]: It is crucial to orient the audience in the space, and if necessary limit the search to an achievable area; otherwise, users might end up lost and frustrated looking for something they cannot find. Carefully placed visual markers and legible maps can give clear and understandable feedback and instructions to the visitors, thereby promoting the museum's physical exploration, which would ultimately encourage teenagers to discover the exhibits and engage with them.

Lessons learned under the topic "Gameplay" aligns with the *Ocean Game* findings [25], Nilsson and colleagues [53], and Cabrera and colleagues [9]. Touring the museum with a game-based strategy stimulates competition among visitors [25]. These strategies can influence the level of engagement with the museum premises [53]. We also echo Cabrera et al. [9] in paying attention that the gamified mobile experience does not take over from the exhibits in the museum. For instance, in our game-based strategy, MoCP-HE, visitors can look at the exhibits on the shelves to correctly answer a question on their smartphone. The design of the experience should be aligned with the museum's purpose, and not just encourage teenagers to look at the screen but to switch their focus back and forth to the museum exhibits.

As Falk recalls, "one size does not fit all" [35], hence museums and curators should consider their goals and embrace the strategy that would best suit their purpose. Different strategies can be implemented for different intentions depending on what museums want to highlight in an exhibition and the type of experience they want their visitors to have. Together, these lessons learned form a roadmap to guide the development and maturation of gamified mobile museum experience solutions targeted at teenagers (15-19 years old). We envisage that these findings can inform the design, research, and evaluation of interactive technologies in natural history museum contexts.

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