



“Listen to the Whole Story!”: Narrative-Driven Learning in Cultural Spaces Through AR

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Abstract. Although Extended Reality technologies, such as Augmented Reality (AR), are increasingly used in museums and other public cultural spaces to enhance visitor engagement, relatively little research has explored how the design of interactive digital storytelling and specific modes of content communication influence visitors' cognitive processes and understanding of cultural content. This study contributes to this research gap by empirically examining visitors' perception and comprehension of cultural content communicated through AR experiences. Building on prior work that aims to enhance visitor experience in cultural settings, the purpose of this research is to explore the role of immersive storytelling in conveying cultural knowledge in ways that are both meaningful and attractive, while also gaining deeper insights into associated learning processes and content understanding. To this end, the paper presents two case studies deploying AR storytelling in a museum and a museum-library, respectively, and reports preliminary findings from two user evaluation studies examining how the cultural content was perceived and understood in each context.

Keywords: Immersive Learning in the Museum, Interactive Digital Storytelling, Augmented Reality, User Evaluation.

1 Introduction

Extended Reality (XR) is gradually appearing in every aspect of cultural and social activity. In particular, the use of immersive technologies in cultural spaces has proven to be a valuable approach for enhancing audiences' experience and active engagement with cultural content [1-4]. The relationship between immersive technologies and cognitive learning processes in cultural heritage contexts constitutes a broad and innovative research field, marked by strong scholarly interest and significant potential [5-7]. Such research concerns on one hand the way interaction and multisensory experiences can contribute to learning [8-9] while on the other hand, points to the evaluation and assessment of their effectiveness [9-11].

Thanks to advanced technologies and contemporary curatorial design, certain museums distinguish themselves by emphasizing the features that make them unique and by offering visitors an informative, multisensory environment that captures visitors' attention and inspires creativity and curiosity [12]. It has also been well established that storytelling plays a significant role in shaping cognitive and affective experiences [8, 13-15]. Within museum contexts, it enhances engagement and immersion, leading to its integration into curatorial practice as a means of fostering both personalized and collaborative forms of visitor participation through audiovisual media, interactivity, and narrative-driven technologies [16-18]. In this field, extended research work focuses on the use and design of AR affordances, for delivering information, communicating content or interpreting artefacts through storytelling [19-21]. However, the role of well-structured [22] and dramaturgically complete interactive stories, together with the largely unexamined influence of narrative design choices in immersive environments on visitors' learning, calls for further investigation and evaluation studies [20, 23]. Our hypothesis is that research in these directions could support more meaningful heritage communication and content understanding.

Against this background, this study aims to examine the role of immersive storytelling, in this case in the form of Augmented Reality (AR), in absorbing cultural content in an engaging way. The objective is to identify, design, and test specific narrative strategies that enhance the visitors' overall experience, particularly by facilitating a

deeper understanding of the content encountered and enriching the learning process. The key research questions that frame this study are: (a) can immersive storytelling enhance content comprehension in cultural spaces; (b) can specific narrative design strategies affect visitors' understanding and interpretation of cultural content, and how; and (c) in what ways can multimodal stimuli (visual, acoustic, spatial, interactive) through AR applications influence visitor engagement and learning processes in cultural spaces.

To address these questions, the study focuses on two AR experiences that move beyond fragmentary content dissemination, to deliver well-structured interactive digital narratives in two cultural spaces respectively. Our analysis compares both content design and presentation as well as the narrative design strategy chosen for each application. Furthermore, this study presents the preliminary outcomes of the user research conducted for each case, with particular attention to how visitors perceived and received cultural knowledge.

2 Background Research

XR technologies, employed for engaging experiences of higher or lower interaction [24-25], play a prominent role in reshaping many aspects of cultural heritage education, using simulation, digital reconstruction of artefacts, and immersive storytelling. They promote and facilitate user engagement, emotional connection, and knowledge retention [26-28]. They also enhance attention and motivation [29] and even affect in some cases where visitors emotionally engage with the cultural content they encounter [30]. During such an experience, visitors shift from passive viewers to active participants, receiving more vivid, personalized knowledge and in-depth contextual information about cultural settings, events and artefacts, [24, 26, 28, 31-32].

At the same time, digital technologies have affected the way stories are presented, giving rise to interactive digital storytelling. Each advancement in technological media that enables telling stories in a new and potentially compelling way can be profoundly effective. It is argued that the use of technology which makes a story clearer and more memorable contributes to the retention and understanding of information [33]. As interactivity has been dynamically introduced in the field of storytelling, Miller [34] defines Interactive Digital Narrative (IDN) as a platform of digital media and interaction serving narrative purposes for both fictional and non-fictional stories, and Koenitz [35] as “expressive narrative forms implemented as a computational system [...] and experienced through a participatory process”. Such stories reach the public through digital technology and media [36], and, depending on the techniques employed, even a dull or difficult topic can become vivid and engaging for the audience [37].

On this basis, more cultural institutions and organizations tend to use digital means (databases, archives, virtual tours, VR/AR) to disseminate cultural heritage knowledge and create immersive learning experiences for their audiences [38], within environments either designed specifically for learning, or where learning occurs atypically through immersion [39]. In any case, the objective is to raise the public's awareness and reception of cultural knowledge, through the creation of interactive spatiotemporal connections of objects and spaces [38, 40].

According to Mystakidis and Lympouridis [14], although learning most naturally occurs in a physical environment, immersive learning experiences can also effectively serve this purpose when required. Comparable conditions can be artificially constructed within virtual environments that emulate the original context and foster immersion through the simulated system, the psychological impact of the narrative framework, and active engagements with the tasks at hand. Research on immersive learning environments should therefore address both the design and development as well as the evaluation dimensions of the endeavor [39].

The use of AR technology is ideal for preserving the physical authentic features of a cultural space, and enriching it with digital information, to achieve a deeper and multidimensional connection with its meanings. In museum settings, it demonstrably adds educational value and supports learning, in part because its interactive features stimulate social interaction and active participation among visitors [41-42]. Institutions deploy AR not only to present untold narratives but also to layer supplementary content onto exhibits, thereby enriching the visitor experience and making learning more playful and engaging [43-44]. In theory, by overlaying digital elements, such as video, graphics, or location-based data, onto the physical environment [45], the users' perception and understanding of what they encounter is augmented [46]. Therefore, it has been argued that the use of AR technology in cultural spaces significantly enhances learning through: a) digital interpretation, providing visitors with nuanced information about physical objects/exhibits [3], b) storytelling, making the cognitive experience more engaging by activating visitors' emotional involvement [6], c) enhancement of the realism of an exhibit through the synthetic dimension [47] d) personalized experience, with the provision of alternative paths of information through interactivity [48].

3 Methodology

In this context, our design approach is deeply rooted in the notion that the integration of multiple sensory and representational modes (visual, aural, tactile, textual, spatial) of content, creates multimodal environments that support meaning-making, enhance engagement, and enable multisensory and cognitively engaging encounters with cultural heritage [49], [50]. Focusing on delivering complete structured narratives with multimodal AR interactivity, the study was conducted based on the design, implementation and evaluation of two case studies, as presented below.

3.1 Two AR Applications

The first case study (henceforth C1) is the application “open AiR Tériade” which was developed for the Museum-Library Stratis Eleftheriadis-Tériade in Lesvos, Greece. It presents the story of the novel “Daphnis and Chloe” written by Longus in the 3rd century A.D. and illustrated much later (1960-1961) by the famous painter Marc Chagall – upon commission by Tériade – creating one of the 26 “Great Books” exhibited in the Museum-Library. The experience begins inside the museum and continues outdoors, guided by a series of interactive scenes on the mobile screen. The visitor interacts with Mark Chagall’s illustrations and discovers the literary work “Daphnis and Chloe” through an interactive digital narrative (Fig. 1).

The second case study (henceforth C2) is the application titled G.GounARo which was developed for the G. Gounaropoulos Museum in Athens, Greece, and presents the painter's reflections and opinions regarding the art of painting. Starting from the Museum courtyard, the visitors listen to a short narration that introduces them to the painter's world and guides them to the next step. The application then takes place inside the Museum, initially in the hall and then in the painter's room-workshop where a fictional story unfolds, inspired by the painter's works. In addition to audio narrations, the application's content includes images of paintings processed into videos and 3D objects, which support interaction with the user and enhance their experience (Fig. 2).



Fig. 1. User experience when using “open AiR Tériade” app.

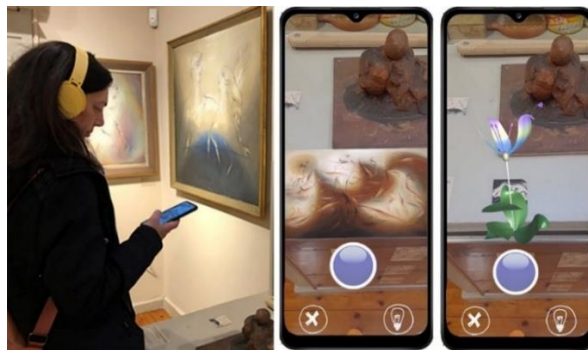


Fig. 2. User experience when using “G.GounARo” app.

With regard to spatial navigation, C1 follows a linear path that extends from the museum interior to the surrounding outdoor landscape. Although the experience begins indoors, the narrative unfolds primarily outdoors,

along a route marked by AR triggers placed on tree trunks within the museum's olive grove, leading the visitor towards a small chapel. The short distances between markers support the sequential progression of the narrative.

By contrast, C2 adopts an indoor-oriented spatial structure following a brief outdoor introduction. A bronze sculpture of Pan by Aristides Patsoglou, located near the museum entrance, is integrated into the narrative as a framing element, functioning as the initial narrator. The experience then continues inside the painter's former residence, where visitors are guided between stops through auditory cues, with key words directing them to specific artworks on the ground floor.

3.2 Featured Content and Learning Objectives

As far as the content of each AR application is concerned, in C1, the designer's intention was to present an immersive interpretative experience about Marc Chagall's illustrations (featured cultural items of the Museum-Library) as well as the literary work "Daphnis and Cloe" which is of comparable significance to the paintings and constituted the narrative baseline of the application. Finally, another purpose of this application was to present the works of art which were not exhibited in the Museum-Library due to space constraints. Therefore, paintings which were already digitized and physically stored at the museum's warehouse, were used to "illustrate" the narrative of the application.

In C2, the designer's intention was to present the more abstract and unseen aspects of the museum's exhibitions related to the thoughts and views of the artist himself based on his personal notes. Visitors can identify the artist's reflections through the application and the original narrative, not only on the augmented works but also on the physical paintings exhibited in the Museum, creating a more profound and deeper understanding of the artist's intentions and worldview. To sum up, while in C1 the learning experience is focused on the artefacts and the content of the works of art, in C2 emphasis is given to the artist, his character and mentality as reflected in his work. It is essential to acknowledge that the common denominator in both cases is that the provided digital content is not accessible to the public during the conventional visit to the museums.

3.3 Featured Content and Learning Objectives

In C1, the narration is organized around a predominantly progressive narrative, which is accompanied by brief descriptive pauses in the form of narrator instructions. These pauses lead to internal homodiegetic flashbacks presented as micro-narratives (Fig. 3). The main narrator of the application is a character from the literary work, old Phylitas, who addresses the user directly and provides guidance throughout the experience. In this way, the narrator fulfils both a narrative and a communicative function, conveying the story while supporting continuous interaction between story and user. Therefore, the character of Phylitas functions as a homodiegetic narrator, as he participates in the story world. To enhance the liveliness and appeal of the narration, first-person testimonies are consistently used in micro-narratives, while elements of personification are also employed in selected instances.

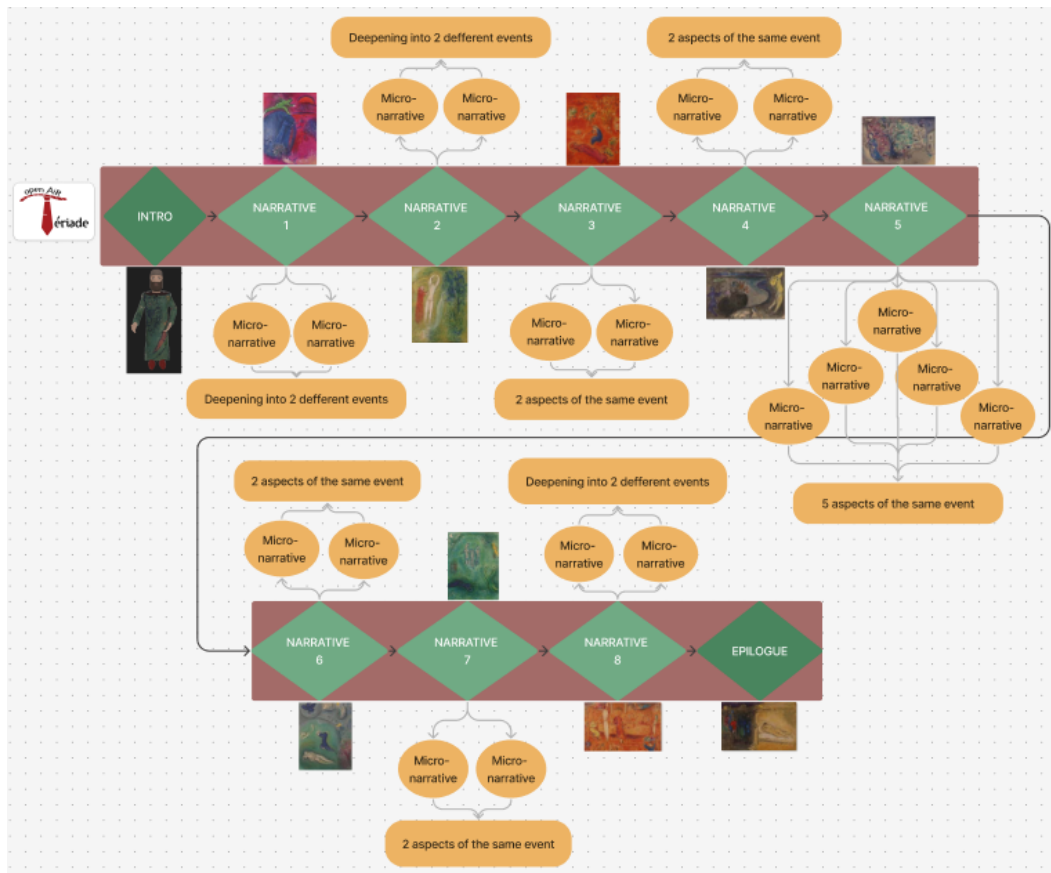


Fig. 3. Flowchart for the “open AiR Tériade” app.

In C2, the story is told by three characters: a) Pan, as a heterodiegetic narrator, who is heard at the beginning and also at the end of the tour for reasons of balance, b) the painter, whose narrative, according to Genette [51], constitutes a homodiegetic undertaking, as it refers to events in his life, which precede the point in time that he narrates, and c) the girl/nymph also as homodiegetic narrator, describing her adventure, as a nested narrative, according to Valoukos [52], as it springs from the painter's previous narrative. At certain points there are dialogues, with the aim of providing vividness and theatricality.

Regarding the narrative structure, both case studies adopt the kernel and satellite model by Cohan & Shires [53], according to which a central sequence of core (kernel) events that build the main narrative is combined (or interrupted) by peripheral to the main story (satellite) events. This structure is used to serve both similar and slightly different purposes in each case. In C1, the main narrative consists of eleven core story scenes, which form a three-act narrative structure, and each scene is enriched by optional micro-narratives (satellite events). The main narrative provides the user with a complete and coherent story, even if they skip satellite events. Although the latter could serve as standalone descriptions, they cannot whatsoever replace the main narrative of the application. The same stands for C2, where the narrative unfolds in a linear sequence of twelve core events connected like links in a chain (see Fig. 4). The omission of a chain cancels the narrative [52]. However, here interactions have a functional role within the kernels and their completion is essential.

In both cases interactivity takes place for transitioning either from one location to the other and activating the respective markers to resume the story, or from the main narrative to micronarratives. In C1, all eleven scenes provide interactive micronarratives, whereas in C2, four kernels out of twelve are interactive, offering satellite events that accompany, complement, and extend the core narrative. Regarding multimodal interaction, both experiences offer throughout their locations sounds, 3D images, animations, music, text and touch.

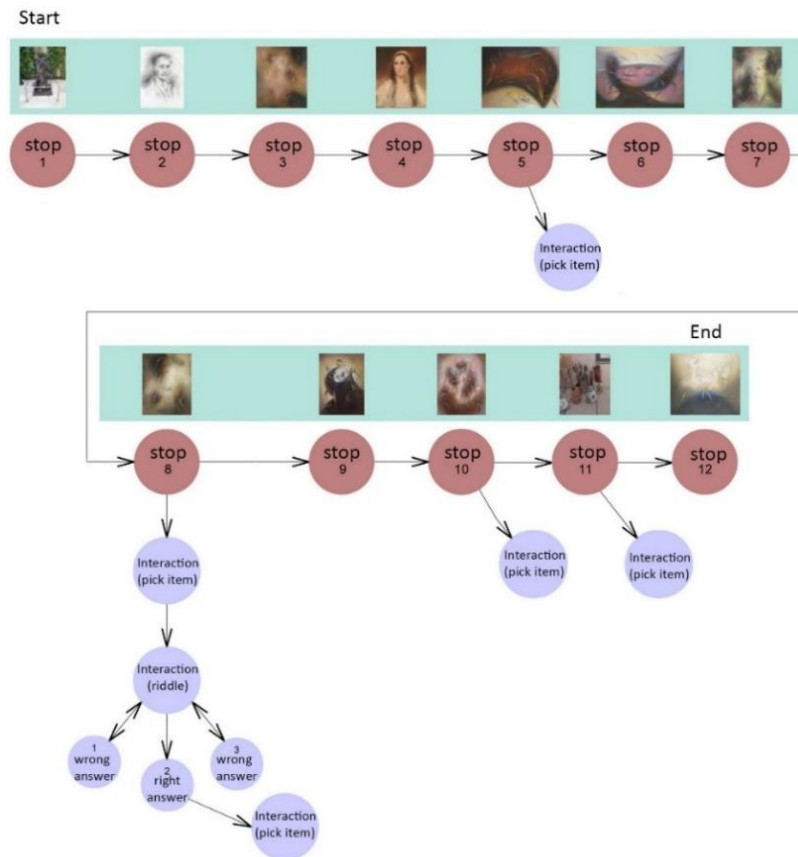


Fig. 4. Flowchart for the “G.GounARo” app.

In C1, multimodal interaction concerns experiencing perspective-taking by activating acoustic narrations of different animated characters on the augmented paintings. In C2, these interactions involve videos, picking 3D objects and solving a riddle. Comparing the degree of interactivity, we note that in C1 we opted for denser interaction points, with at least two interactive triggers in each location, thus offering a higher degree of interactivity and optionally a deeper engagement with cultural content. In C2, the interaction is present in crucial points of the narrative at four locations, providing active user participation to continue the story. It is worth noting that the keywords provided at the end of each narrative to unlock the next and the riddle indicate a more playful narrative design strategy.

To sum up (see also Table 1), in both cases the narrative structure is linear, with a clear beginning, middle, and end. At once, multimodal interactions (sound, image, video, music, text, and touch) support a multisensory experience that is framed by a coherent interactive narrative, which guides visitors each time to the next predetermined learning step through cues. In C2, the content is enriched with a printed brochure giving additional information about the use of the AR application, as well as the exhibits presented. Finally, both cases draw inspiration from the works of painters; however, in the first case, the adaptation of a literary work into the final narrative script plays a key role in shaping the presentation of the artworks.

Table 1. Featured content & content communication.

	C1	C2
Spatial navigation	Outside the Museum-Library	Inside the Museum
Interaction	Multimodal (narratives, images, music, 3D objects, animation)	Multimodal (narratives, images, music, 3D objects, video)
Narrative	Adaptation of the literary work “Daphnis and Cloe”	Original story based on the painter’s notes & inspired by his paintings

Narrative structure	Linear sequence of 11 scenes. Core events combined with secondary	Linear sequence of 12 scenes. Core events combined with secondary
Content	Not accessible to the public	Not accessible to the public
Accessibility	during typical visits	during typical visits
Featured content	Illustrations and literature found at the Museum-Library	Thoughts and views of the artist on specific topics and the meaning of painting based on his personal notes
Focus on learning experience	On the artefacts and their content	On the artist's character and mentality reflected in the artefacts

4 Preliminary User Evaluation Results

In both cases, the user research was conducted in real-world conditions, in situ, within the respective museum spaces and followed a structured yet unobtrusive methodological approach. We opted for a qualitative approach, as it is suitable for the in-depth description and analysis of phenomena or situations as experienced and articulated by participants [54-55]. More specifically for the qualitative data collection, we employed participant observation, and post-experience semi-structured interviews. Observation offers the advantage of capturing immediate information about participant behavior, as it takes place in the natural setting of the activity. The interviews followed a semi-structured format which, while based on predetermined questions, allowed flexibility in the order of questions, the adaptation of content to each interviewee, and the inclusion or omission of relevant topics during the discussion. An information form outlining the research objectives and procedures was distributed to all participants, and the respective consent form was signed.

User evaluation data were analyzed independently by two researchers across the two case studies. Each researcher initially conducted an autonomous thematic analysis, developing codes and themes for each case separately. The researchers then compared their analyses to identify common patterns and points of convergence, resulting in a synthesized set of shared themes that strengthened the reliability and validity of the findings. Given the small user sample in both cases, no qualitative analysis software was used; instead, the final thematic framework was established through iterative discussion and final consensus. Here we report our preliminary evaluation results that primarily focus on the contribution of immersive storytelling to learning and content understanding within cultural settings, while a full-fledged evaluation report and further research is planned in future work.

4.1 User Research Profile

In C1, the evaluation took place at the Museum-Library during scheduled meetings. Upon arrival, participants were guided to the Hall where Marc Chagall's works are exhibited. A brief contextual introduction was provided, outlining the scope of the experience, without offering any instructions on how to operate the application. Participants then used the application independently, while their interaction was discreetly observed to avoid discomfort or disruption of the experience. Upon completion, participants were invited to return to the starting point of their visit for as long as they wished, after which a semi-structured interview was conducted. Eleven (11) people participated in the research, five (5) women and six (6) men. Women's age was between 23-59 and men's between 23-67. All participants were university graduates, five (5) of them had no previous experience of using AR applications and two (2) had never visited the Museum-Library. Regarding the familiarity with the story of the novel "Daphnis and Cloe", three (3) participants knew about it, four (4) participants had a vague idea about the story, and four (4) had no prior knowledge.

In C2, participants were given information sheets about the application before using it. Then a brochure with operating instructions and information about the application's content was handed out. Participants who hadn't visited the museum before were asked to spend a few minutes at the painter's ground-floor studio to have a first impression of the exhibits. For practical reasons, three mobile phones were used, and users began the AR tour a few minutes apart. During application use, participants were also discreetly observed. After completing the experience, participants were guided to the place where the interview was conducted. Thirteen (13) people participated in the user research, seven (7) women between 18-57 years of age and six (6) men between 18-70 years of age. Eight (8) participants used an AR application for the first time. Regarding the participants' relation to the Museum and the exhibits, three (3) of them were frequent visitors, two (2) had not visited the museum for several years, and the rest had never visited it before.

User Research Results

The qualitative analysis resulted in the identification of seven themes that reflect participants' views as shown in Table 2.

Table 2. Results: theme codes, titles and descriptions.

Code	Theme Title	Theme Description
T1	Content comprehension	Immersive content reception in terms of comprehension and meaningfulness
T2	Cognitive process	Narrative impact on participant cognitive learning processes such as attention, memory, information processing and desire for further knowledge
T3	Appeal and connection	Engagement and connection with the museum environment and its artefacts
T4	Experience enhancement	Perception of immersive experience including sensory stimuli and emotional engagement
T5	Interactivity	Interactivity in terms of both functional and experiential aspects of the visit
T6	Usability and immersion	Usability and onboarding to the immersive experience
T7	AR and user reflections	Reflections on AR technology in cultural settings

Based on the research questions and according to the identified themes, our preliminary findings indicate that immersive storytelling with a complete and structured narrative contributed to participants' understanding and interpretation of museum content by providing coherence and contextual meaning, as the narrative stories were clear to almost all users. As the following users commented: "I liked that I saw images with a background story. It made it easier to understand what the artist was depicting and trying to communicate. It had a sequence, a beginning, a middle, and an end." (C1/U1), "The central narrative is nice, but you also hear the intermediate micro-narratives of the characters, which is practically where you begin to understand what each person is saying and what they are feeling. This is very interesting." (C1/U9), "It stimulated all your senses, it created a world for you. It made you think deeper in your mind. You are part of the story, active, not passive...I liked the speech, the text, the narration." (C2/U1), "The script was excellent and hooked you in the story, connecting image with sound." (C2/U10).

Participants reported that the use of narratives, audio, and visual modalities supported cognitive processes, such as attention, memory, perception, and information processing, while also encouraging curiosity and motivation for further knowledge. They also noted that information was communicated effortlessly, in a more refreshing and illuminating manner. More specifically, users commented that: "The story entered the painting, and I could see the characters involved within it. Until then, I had approached the paintings mainly in visual terms (colors, romanticism, eroticism), but now I know much more about the story behind them." (C1/U3), "The visitor has the opportunity to escape the dryness of a typical museum visit and, through the app, delve deeper into the artwork and the painter's philosophy in a more interesting way. I would like to learn more about the painter." (C2/U9), "It revitalized the Museum's exhibition and facilitated the delivery of information, while at the same time allowing for deeper engagement with the artist and his world. I will look for further information about the painter. I believe it would be a useful application in education." (C2/U12).

The participation in the experience seemed to strengthen engagement with the museum space and its content, encouraging participants to reapproach artworks with a different perspective and a stronger sense of connection. According to participants' own words: "What really struck me was that when I went upstairs again, I saw the exhibition in a different way and didn't leave the hall right away. I didn't rush. I tried to notice all the things mentioned in the titles of the paintings. I think I better understood Chagall." (C1/U8), "The app enhanced my experience. I feel more connected to the museum." (C2/U1).

Immersive and sensory elements were perceived as enriching the museum visit by activating emotional involvement and participation over mere observation. The following comments support this claim: "The audio stimuli were pleasant, and the narration of the main story was well written, in an engaging way. It was like listening to someone telling a fairy tale. It enhanced the experience 1000%!" (C1/U1), "Both sight and hearing were activated. The whole walk felt complete. It took place in a very special environment. As for emotions, having the background of my first reading, it didn't bother me; (on the contrary) it probably took me further. I liked it, I felt the sweetness of the novel again." (C1/U10), "The digital part enriches the content. The sound and the modalities

enhance the exhibition and familiarize the audience with the painter.” (C2/U10), “Technology illuminated other parts of the work, and all the elements made you get to know the painter as if in a movie. They wouldn’t affect you in the same way if you read them in a book.” (C2/U11).

Interactivity played a significant part in participants’ guiding and engagement, providing playfulness, exploration, and perspective-taking. As the following users commented: “I particularly liked the part with the bird because it showed different perspectives. You had the same story, but now you could hear it from someone else’s point of view, and it was interactive and playful.” (C1/U1), “I liked the interactivity, that I could follow the story and learn that this painting represents that part of the story. That’s what caught my attention; otherwise, it wouldn’t have made such an impression on me.” (C1/U2), “I liked the part that I could pick the 3D objects.” (C2/U8), “I liked the interactivity.” (C2/U8).

At the same time, certain challenges were reported, mainly related to the use of technology and to becoming familiar with the type of experience offered. Particularly at the beginning of the experience participants described feeling distracted and having difficulty immersing themselves in the story. As per the actual comments: “At first, I was a bit confused. I didn’t realize I had to tap the little character to move on. Once you interact with the first character, it kind of takes care of itself. Up until then, it felt a bit awkward. I was just tapping different parts of the screen.” (C1/U8), “At first, I didn’t immediately understand how to start, but then it was clear and it felt nice, like a game. Maybe there should have been more instructions from the beginning.” (C1/U3), “I had a hard time at first, because I was trying to find the right distance to aim with my mobile screen.” (C2/U11).

Finally, using Augmented Reality was positively commented on offering a refreshing element to the museum experience, although some reservations were also expressed regarding its appeal to young children or less technologically familiar users. The following users commented: “Such applications would certainly contribute to other cases as well. It would also give more meaning to the library part (of the museum), since it’s about stories.” (C1/U6), “AR is one of the basic things that enhances the experience. You can achieve things you can’t imagine. Only someone older might say oh I don’t want to use this, I’ll just see the painting, because they are not familiar with this type of tour. It would be better to communicate it and say Look, it’s easy!” (C1/U1), “The exhibits are more interesting in a different form. I would like similar AR apps in other museums, too.” (C2/U5), “The app worked complementary and helped a lot in making the tour more interesting. AR is the future for museums.” (C2/U13).

5 Limitations

At this point, we acknowledge as a limitation of this study that the reported preliminary results reflect the instant evaluation of the users regarding the learning procedure. The outcome of this study reflects the first impression and the intentions of participants e.g. to actually read the book “Daphnis and Cloe” in C1, or to actually seek more information about the painter in C2, and could not be considered as a long-term assessment which could give results about the participants’ depth of knowledge acquisition and degree of information absorption after the use of these applications. To measure the long-term learning impact, further research should be conducted on the same participants and investigate the learning impact from their visit to the museums. Additionally, the conclusions are limited and cannot be generalized due to the small scale of the evaluation. This limitation could be addressed in future work through a larger sample of user research participants and mixed methods protocols of evaluation.

6 Conclusions and Future Work

Despite the limitations, this research study indicates that within the framework of cultural heritage settings, XR technologies have an important role to play in the creation of immersive learning experiences. More precisely, the preliminary results demonstrate that careful design of immersive storytelling can significantly aid cultural interpretation and learning by offering coherent narratives and meaningful connections between artworks and their cultural context. The use of multimodal elements successfully supports cognitive processes, while also increasing curiosity and motivation for learning. AR storytelling, implemented in this case as a linear narrative with branching micro-narratives, can draw and sustain visitors’ attention and, in doing so, support the comprehension of cultural artworks and their more complex features. By situating interpretation within an unfolding storyworld that is anchored in the museum environment, the experience encourages visitors to connect with the space and to develop a more reflective appreciation of the exhibits. Interactivity also plays a central role in guiding exploration and maintaining engagement. However, at the beginning of the experience, we identified certain issues that appeared to temporarily distract participants from content comprehension. This is frequently reported in comparable interactive experiences as part of the onboarding phase, during which users tend to focus on the

interaction logic and the overall experiential framing rather than on the content itself. This aspect warrants further examination, in order to explore ways of mitigating this challenge in the interest of supporting the learning process.

Beyond discussions of innovation and technological possibilities of AR in museums, these preliminary findings offer empirical, user-centered evidence of how immersive storytelling can meaningfully support learning, interpretation, and visitor engagement. Within this frame, AR is not treated as a mere means to an end, but as an integral component of structured narratives and multimodal design, contributing to more meaningful heritage communication. In summary, the findings add to the body of work demonstrating that AR narratives can transform museum visits from passive experiences into substantial, and cognitively rich learning experiences. Future research could build on the above insights by systematically investigating further how different types of immersive digital narratives influence visitor learning, engagement, and interpretation, and how complete narratives affect immersion and long-term learning in museum contexts.

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Author Contribution

Conceptualization, VR, EP; Investigation, VR and EP; Methodology: VR, EP and AC; Project administration, VR; Software, VR and EP; Supervision, AC; Validation: EP, VR and AC; Visualization, VR and EP; Writing – original draft, VR and EP; Writing – review & editing, AC, VR and IP. All authors have read and agreed to the published version of the manuscript.

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