

Ex Machina: An Interactive Museum Kit for supporting educational processes in Industrial Heritage Museums

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Abstract. The aim of our project was to create an interactive museum kit in order to prepare young elementary students for their visit the Industrial Heritage Museum of Hermoupolis, enhancing their experience and promoting a “hands-on” learning approach. This paper presents field research, design decisions and the evaluation of the Ex Machina Museum Kit. The system comprises of 4 tangible team games, 4 documentary-style videos presenting information relative to the theme of the museum’s collections as well as an interactive storytelling and decision-making game. Finally, a preliminary evaluation presents the benefits that this project would provide to the elementary school students visiting the museum.

Keywords: Interactive Museum Kit, Industrial Cultural Heritage, Storytelling, Interactive Game, Interaction Design.

1 Introduction

As part of the Interactive Systems Design course at the University of the Aegean, we were prompted to create a board game as a visit companion for a museum of our choosing at the region of the island of Syros. From a field visit to the Industrial Museum of Hermoupolis, it became evident that a number of ideas can be explored to fulfill the design brief. This museum was chosen as it houses an extensive collection of diverse industrial exhibits, too many to go over in the limited time of the tour without any previous knowledge.

We focused on primary school students, researched museum-pedagogical issues, and interviewed teachers as well as the museum employees (guide, curator, and archivist). We realized that even though the students are excited about the visit, they usually don’t retain the majority of the information that they are being presented. We wanted to create a system that would stimulate the students’ interest, encourage them to actively ask questions during the visit, and help them retain more information after their visit. Our research led us towards playful learning, tangible interfaces, and group activities supported by interactive technologies. With those in mind, we created an interactive system

that embraces the whole visiting experience. It includes the student preparation phase before the visit with games and short documentary-style videos and an interactive storytelling phase to supplement the learning experience [1–3]. The interactive museum kit is meant to be sent to schools before their visit in order to support the learning processes related to the actual museum content [1, 4].

2 Methodology

We aimed to design an interactive museum kit that will prepare elementary school students for their upcoming school visit to the museum and, also, enhance their visitor-experience. During the formation of the design brief and preliminary research, some typical challenges we would have to overcome were: a) the interactive museum kit should be compatible with the current museum practices (curation and available educational programs), b) to present the learning content with the appropriate pedagogical practices, c) to be aligned with the Greek national educational curriculum and meet teachers' pedagogical preferences, and d) to provide engaging and playful activities for students.

In order to address these challenges, we followed an iterative design approach that was presented to us during the university course [5]. In Figure.1, each studio design phase is presented. In the following paragraphs, we describe how each of them was adapted for our project.

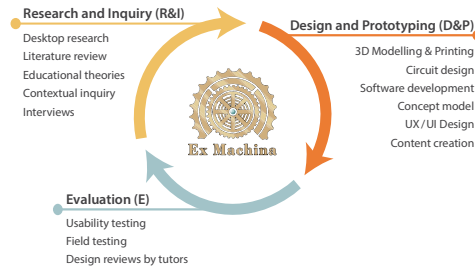


Fig. 1. The iterative design approach followed

2.1 Research and Inquiry (R&I)

This phase included desktop research as well as contextual inquiry, which acted as complementary to the findings related to on-going works and trends [6, 7]. The former referred to related projects and interactive systems achieving similar goals and/or offer similar user experience (UX), and to educational theories that will help us combine museum-teaching content with the appropriate technologies in order to accomplish specific learning objectives [2, 8]. As for the latter, there were two situations we needed to gain an understanding of them: museum approaches and teaching practices in elementary school. Therefore, we conducted semi-structured interviews with both the director of the Industrial Museum of Hermoupolis and four (4) elementary school teachers, who gladly accepted our invitation.

2.2 Design and Prototyping (D&P)

This phase covered the aspects of conceptual design and prototyping, including 3D modeling and printing, circuit design, and software development. The first step was to specify the learning content and collect information about it: the history of Hermoupolis (capital of Syros Island), its foundation, and flourishing throughout the 19th and early 20th century. Taking into consideration the museum's curation and comments from teachers, we concluded that our interactive system should embrace the whole museum visiting experience, which begins in the classroom and ends at the museum. For this reason, it took the form of a museum kit.

The presented system architecture consisted of two parts (see Figure 2): a) classroom pre-visit activities and b) museum activities during the school visit. We designed four (4) tangible mini-game artifacts each one including playful learning activities for a group of 3-5 students, which take place in the classroom. At the museum, after the guided tour, students, forming self-selected groups, participate in an interactive storytelling game. In this game, they help the hero to establish a textile factory by collecting relevant exhibit items from different museum collections and guiding his decision.

2.3 Evaluation (E)

The Evaluation phase includes preliminary empirical testing activities about the implemented technologies and prototypes and a field study with user participation.

The first part of the evaluation was iteratively conducted throughout the design process in the classroom by tutors and other university students. Its main focus was to gather feedback about the usability of the tangible mini-games artifacts and the interactive storytelling game in order to address potential issues in time.

The following field study took place in a school class simulation room regarding the pre-visit activities, and, as for the interactive storytelling game, in the setting of the Industrial Museum of Hermoupolis, with high-fidelity prototypes and user participation. This part's objective was to evaluate the design goals, usability, and also overall user-experience (UX) of our educational interactive system.

3 Related work

Interactive systems that influenced our work are briefly presented in this section. Emphasis is given on projects and technologies that introduce storytelling approaches, decision-making activities, or aim to enhance UX in museums (before, during, or after the visit).

"*Museum in a Box (MiaB)*" [9] is an educational interactive system that brings museum content to schools by providing them with hand-held tangible replicas of real exhibits in the form of 3D-prints, card-postal, documents, pictures, maps, etc. Every kit is tailor-made to meet the specific needs and content of the museums. The system uses a Raspberry Pi board along with an NFC Reader and two speakers. Users interact with NFC-embedded physical objects to hear an audio story associated with each one. The idea of 3D-printed tangible replicas, which allows students to interact safely with museum

items, as well as the concept of connecting them with a story influenced creatively our work.

“*A Gift for Athena*” [10] is an augmented reality application for the British Museum, related to the Greek exhibits and the "Gallery of the Parthenon". The game is about the celebration of Athena’s birthday at the Acropolis. Users are asked to return the gift (tunic) of the goddess by completing the silhouette recognition and the exhibit collection using their mobile's camera to be able to retrieve it. As a result, the interest in the exhibits is being increased due to the playful learning and engagement. The game parts that our team examined are the characters which create a thematic context (conditions, space, time), set either short-term goals (solving each challenge) or long-term ones (offering a gift/tunic to the goddess), and challenge the player to act (interaction with the application and connection with the real environment) to achieve them. Also, the use of the exhibits as part of its storytelling and plot development, creating connections between the real (Museum) and the virtual world (application) determined the role of the exhibits in the “Ex-Machina” museum kit and the gamification of the students' museum experience.

“*Tinker Island*” [18] is a strategy mobile game about survival on an unknown island. Players have to survive through decision-making activities. The narration function is activated during exploration and describes the player’s condition, who is called upon to make decisions to reach its end. Each exploration area unfolds a different plot. Player's choices can lead to the continuation of the narrative, either with a negative or a positive effect, and finally to the completion of the narrative, which will determine his status. We found it interesting to incorporate the concept of continuation alternatives in the narrative for the interactive storytelling game in the museum. In this way, different game experiences will be offered depending on players’ choices.

4 Research & Inquiry

4.1 A definition of museum kits

A museum kit (or Museum-in-a-box) is a portable collection of loanable items for educational purposes, which includes, for instance: museum artifacts or replicas, illustrations, and other audiovisual materials, teaching resources, educational games, etc. [3, 11]. It can be implemented before, during, and/or after the school visit to a museum. However, according to Black [3] conducting pre-visit activities helps students get familiarized with the museum content. It is a common practice among museums to provide a variety of educational kits covering a wide range of themes. Every kit should be developed carefully by articulating specific learning goals and providing methods by which these goals will be accomplished and assessed.

4.2 Educational approach

Among the different functions museums perform, education is one of the most prominent as they provide various learning experiences to their visitors [12]. However, the

settings within which learning takes place (e.g. usually self-motivated, flexible museum/learning content, no evaluation, etc.) make them non-formal learning environments [12, 13]. Taking these into account, Constructivism as a theory of education seems appropriate to be applied to museum contexts [14], and hence, our educational interactive museum kit was designed and developed from a constructivist perspective.

Constructivism maintains that learning happens in social contexts and requires the active participation of the learners in which they construct their new understanding by reflecting on their living experience and their prior knowledge [14]. Furthermore, according to Hein, active participation can be achieved by fostering a supportive learning environment that engages learners in both hands-on and minds-on activities and encourages them to interact with each other, to experiment, and discover new meanings. Probably, the most important point here is that learners' newly acquired knowledge should not be evaluated based on external reality factors (true/false conditions), but whether it is coherent and leads to reasonable actions.

5 Design and Prototyping

As the collection of exhibits in the Industrial Museum of Hermoupolis is diverse, we decided to design four (4) games, for the major sections of the museum. The museum has six (6) sections, the first is about the beginning of Hermoupolis, typography, and glassware, the second is about trade the main reason why the island's economy flourished during the 19th century, the third and fourth rooms house exhibits related to marine travel and maritime craftsmanship, the fifth room contains exhibits related to industrial cultural heritage while the sixth room houses periodical exhibits and therefore was not included. Considering the limited time for our project we chose to fully prototype three (2) mini-games.

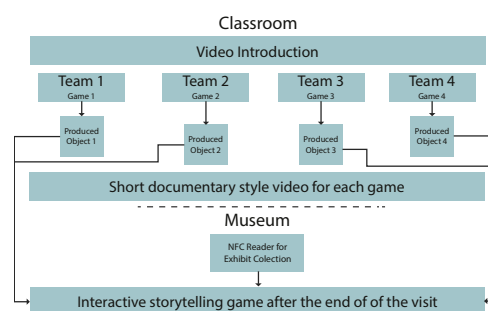


Fig. 2. “Ex Machina” system architecture

Through a set of interviews, we realized that the time teachers could dedicate to a museum kit is limited so it's not realistic to assume that all pupils would be able to play with all games. For this reason, we composed short videos (1-2 minutes long) meant to be seen after each group of kids finishes their game. This way each group of pupils will have general knowledge of all the topics of the museum but will be "experts" in the room whose game they played. From interviews we conducted with teachers it became

even more evident that, especially in primary school, teamwork is promoted, and pupils learn better when they use “hands-on” approaches to solve problems or puzzles. Therefore, following the constructivist principles, we have integrated these concepts, as well as “learn by doing” and experimentation into the playful learning activities of tangible mini-games. Moving forward with our project we took into account that the system we designed was not to overshadow or affect the museum tour itself. For this reason, we decided to design an additional game for the end of the tour to “embrace” the whole visit from start to finish in such a way that our system coexists harmoniously with the museum and enhances the overall experience rather than undermine the museum itself. In order to make the final project more coherent, we designed a narrator who will accompany and advise the pupils throughout their interaction with the museum kit. We chose this character to be Mr. Elpidoforos Ladopoulos because, to this day, the ruins of his factory remain in the area and we have rich records of his life and work as well as of his descendants.

Finally, we considered it important to keep a souvenir in the classroom or for each student individually. So, we designed the games in such a way as to produce items that students can then keep for themselves. We also made sure that the items created during class would be used during the final game at the end of the visit, thus making the pupils realize that whatever they were creating in class has value.

5.1 Introductory Video

When the museum kit is connected to the computer, an application launches, and the character of Mr. Ladopoulos appears on the screen. He introduces himself to the pupils and puts them in the historical context in which the story takes place. Then he talks about the games that the class will play and says that the whole process will be completed in the museum. Finally, it prompts the teacher to share the games so that the pupils may start.

5.2 Mini-Games

The beginnings of Hermoupolis - Typography.

After studying the exhibits of the room, we quickly decided that this game would be a letterpress composing stick that the pupils would be asked to complete. We chose one newspaper from those in the display case. We found in the public library of Hermoupolis an article from a 19th-century local newspaper which speaks for the inauguration of the new factory of Mr. Ladopoulos and we adapted it to language understood by pupils. We removed letters from the text that the pupils would be asked to put in the correct places in order to complete the article. When the article is completed correctly, the pupils should get tempera and paint the plate. Then they take the printed paper which will become the “produced object” and print the text on it. Note at this point, the increased difficulty since the plate is read from right to left, its letters, as well as what the pupils had to fill in are flipped horizontally in order to be printed correctly on the paper.

We considered it appropriate to have a check to confirm that the letters have been placed in the correct places on the plate. We made a circuit with LEDs that light up

when each row is completed correctly. The system consists of a battery and 14 LEDs connected in series. The circuit is completed by placing the correct letter in the correct position. Each individual letter contains a wire in specific positions that correspond only to the specific letter. Also, for this game as well as the “Maritime Heritage Room”, we have designed an instruction booklet which users should read carefully to understand the steps of the process and complete the game.

Maritime heritage.

Even though this is largely occupied by the Steam Ship “Patris” shipwreck exhibition and our original idea was to build a game similar to “Battleship”, we considered that this idea has no future so much at the level of interaction as well as creativity, so we decided to design a game that would have to do with the telegraph. Pupils are asked to listen to and understand a sequence of Morse code and complete the “Produced Item” given to them. Having filled in all the words they need to send, a response message will be revealed. This system consists of an Arduino Uno, connected with 2 Buttons, 1 LED, and a Buzzer, which are contained in a 3D printed case. The “Produced Item” they are asked to complete is an order form and the message they need to send is a confirmation.

Trade.

This game would be a kind of locked safe, the code of which would be given in the form of a puzzle to the pupils through production notes. They would be asked to identify numbers and keywords to calculate its combination. Inside the safe is a check which will serve as this game’s “Produced item”.

Industrialization.

The idea Industry room’s game is a 3D gear puzzle. The pupils have to put the gears that would be given to them, in the right places so that when they turn a crank, a hidden door opens a compartment containing the produced object: an “engineering diploma”.



Fig. 3. Prototyped mini-games and museum kit suitcase

5.3 Application for the Video Presentation

After completing the games, the teacher asks the pupils what they did in the game they played and asks them to say a few words about their experience. Then, every team in turn takes their mini-game artifact (each game artifact has an NFC tag at its base) and places it in the special place on the museum kit.

The museum kit has an Arduino Uno with an NFC scanner integrated and is connected with the class computer. The relevant software, which we developed with Unity and C#, is also installed there. When the NFC reader recognizes the embedded NFC tag, it triggers the video playback of the 1-2 minute long documentary-style videos that refers to the contents of the corresponding room of the museum. Their content emerged from our close collaboration with the director of the Industrial Museum of Hermoupolis as well as bibliographic research. The videos were composed by the members of the group, exclusively for the purposes of the museum kit. After the presentation of the fourth video, Mr. Ladopoulos appears and in a short video invites the pupils to the Industrial Museum of Hermoupolis to help him with a problem he faces and reminds them not to forget to bring with them the items they made.

5.4 Game in the Museum

The idea for the game at the end of the visit is a story that pupils shape through choices they make as they play. We wanted to give pupils the opportunity to explore the museum at their own pace and make interesting choices through discussion. In this game we have implemented some constructivist practices mentioned by Ebitz [15]: construction of knowledge through narrative by the main animated character of the story, co-construction of meaning through conversation between students during the selection procedure of museum exhibits for the interactive story game, and story completion based on the choices made by students as performance.



Fig. 4. Screenshot from the interactive storytelling game

The museum kit is connected to a computer, a touch screen, and a projector. Pupils operate a device that allows them to scan cards from exhibits they see to add to their "collection" letting them choose them to move the story forward. Their choices affect the plot and the final story produced at the end of the game. Throughout the story, pupils are asked to collect exhibits with NFC Reader, scan the items they produced in the classroom and, at one stage, discuss with each other and vote from a list of options.

6 Evaluation

6.1 Purpose

A formative usability test was conducted in order to observe and record useful comments, views, and problems of the potential users and university students specialized in product and system design engineering, for the prototype of the museum kit, to highlight ways to improve it [16, 17]. The participation of design students contributed to the holistic supervision of the museum kit, as they could distinguish the parameters that compose the project both at the prototype and conceptual level.

6.2 Target

The main objectives were to observe if the participants would complete the challenges as the design team expected and if they would find interesting and educational the presented information. Specifically, the observation was about the time and the way of the mini-games' completion and the participants' steps comprehension in the game: "The establishment of a textile factory".

Also, an important goal was to carry out the evaluation as close to the real conditions as possible. The evaluation was consisted of two phases: the first took place in a classroom as a simulation of a school classroom in the Department of Product and System Design Engineering because of the equipment granted, and the second, at the Industrial Museum of Hermoupolis.

6.3 User Identification

The participants were five people ($n=5$), two (2) of whom were 12 years old pupils of the primary school and the three (3) were students of the Department of Product and Systems Design Engineering between the ages of 22 and 24. Of all the participants, only one child had visited the museum again and remembered that it was related to Hermoupolis' factories that existed in the past, without details or any information about the historical context of the time. The remaining participants would make their first visit during the evaluation of the system.

6.4 Implementation

The evaluation took place on 1st of February 2020 and the first phase started in a room of the Department of Product and Systems Design Engineering and lasted about an hour. There, pupils and university students were divided into 2 different groups: the first one could deal with the mini-game of Typography and the second with that of Maritime heritage. After solving the mini-game, each group presented to the class the challenge they were called to complete, and videos associated with these mini-games were shown. These documentary-style videos presented information about the historical context of Hermoupolis, and a member of the design team, linked the information

provided with the content of the Museum, avoiding the disclosure of the exhibits and information of the tour, emphasizing more the social, political, and economic conditions of the past. The second phase started in the Industrial Museum of Hermoupolis and lasted about an hour and a half. Participants were given a short tour from the museum director and formed one group, (limited participants), which played the game: "The establishment of a textile factory". During playtime, the team had to collect the exhibits they considered most suitable for each selection round by using the designed NFC reader device, return to the museum equipment area and decide on its final selections, which influenced the narrative and end of the game. The group also had to place the produced objects (check, engineer's diploma, newspaper, order form) on the museum kit at specific phases of the narrative. The design team did not intervene during the evaluation, it formulated short questions after the completion of a user task, asked participants to complete a questionnaire, and conducted semi-structured interviews at the end of each phase.

6.5 Evaluation Results

After each phase, questionnaires were given to teams, which are the Typography (2 people), the Maritime (3 people), and Museum activity (5 people) team. The first phase's questionnaire was the same for both teams, but because user experience comes from interacting with a different mini-game, two different tables were created.

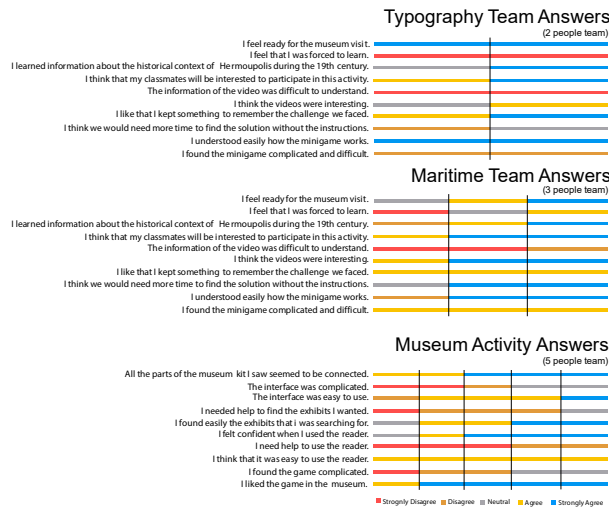


Fig. 5. Results from Typography, Maritime Mini-Games, and Museum interactive Storytelling (each section on colored bars represents a participant response)

Also, the completion task time of each phase and the total time of each one were recorded. It was observed that time durations are close to the initial assumptions of the design team (classroom-2 teaching hours and museum-1 hour). Additionally, a difference in difficulty between the two mini-games was noticed. Although the Typography

team completed its task approximately 4 minutes faster, it's important to mention that the Maritime team consisted of adult design experts. Thus, it is understood that the telegraph is a little more difficult than the letterpress composing stick and needs some modifications that will facilitate its interaction with users.

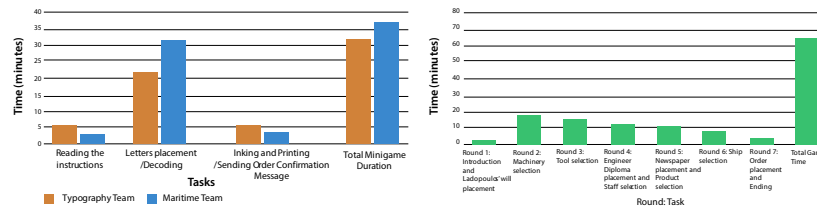


Fig. 6. Task Analysis

Finally, a spontaneous discussion between teams was observed, immediately after the completion of the first phase. Pupils and design students exchanged their experiences explaining the process of solving mini-games and information about produced objects. During the second phase, the team constantly exchanged opinions on the collection and selection of exhibits, was carefully reading the museum labels for more information, and trying to balance the money with the options (expenses/reputation) offered by the scanned exhibits in the game.

7 Summary and Conclusions

The design team looked for interesting and interactive ways to engage an educational visit to a cultural heritage museum. After researching and designing a museum kit for the Industrial Museum of Hermoupolis, the team created and tested the prototype with the assistance of participants who characterized the process as more attractive than a simple visit to the museum.

“Ex Machina” museum kit offers a new educational approach to the Hermoupolis’ Industrial Museum experience, reviving elements of the historical context that’s referring to. Mini-game interactions attracted the interest of the evaluation participants, who described the process at least enjoyable and amusing. A strong project limitation was the simulation of the classroom in the assessment as well as the participation of limited pupils in it. Furthermore, financial and time constraints contributed to the discrepancies in the prototype, in relation to the design intentions, and as a result, changes must be done in order to achieve a better version of the museum kit. Also, the museum kit uses museum exhibits, which reveal the aesthetic perception, skills, and technical progress of the past and brings visitors in contact with various aspects of the daily life, equipment, and people who lived in earlier periods. In this way, museum visit becomes more experiential, visitors understand the value of the cultural heritage and express their respect for it. The interactive activities of the museum kit can be the connection with the

past and the remarkable achievements of previous historical periods, through engagement with the exhibits hosted in the museum, forming a pleasant experience, and enhancing an active cultural participation.

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