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Article

Co-Designing the User Experience of Location-Based Games for a Network of Museums: Involving Cultural Heritage Professionals and Local Communities

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Abstract: The design of location-based games (LBGs) for cultural heritage should ensure the active participation and contribution of local communities and heritage professionals to achieve contextual relevance, importance, and content validity. This paper presents an approach and methods of the participatory and co-design of LBGs that promote awareness and learning about the intangible cultural heritage of craftsmanship and artisanal technology throughout a long-term project from sensitization to implementation. Following the design thinking process, we outline the participatory methods (and reflect on results and lessons learnt) of involving cultural heritage professionals, local communities, and visitors (users) of museums and cultural settlements, mainly: field visits, design workshops, field playtesting, and field studies. We discuss issues of participatory design that we experienced throughout the project such as participant centrality and representativeness, producing tangible output from meetings, co-creation of content via playtesting, and implications from the pandemic. This work contributes a case of participatory and co-design of LBGs for cultural heritage that is characterized by longevity and engagement throughout the design process for three LBGs of a museum network in different cultural sites.

Keywords: mobile location-based games; cultural heritage; local communities; cultural heritage professionals; design thinking; field visits; field playtesting; field study; constructive interaction; MDA (Mechanics, Dynamics, Aesthetics); user experience; evaluation

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1. Introduction

Over the last few years, there has been a notable increase in the development of interactive systems in museums, archaeological sites, and historical buildings or settlements for visitors to access related digital content and augment their experience and knowledge about the cultural heritage (CH) of tangible artifacts and intangible traditions. The development of interactive technologies for cultural heritage is often guided by technological advances and experimentation [1], rather than participatory design practice in co-operation with heritage professionals and local communities such as museum curators and staff, folklorists, archaeologists, architects, exhibition designers, local heritage scholars, experts, and educators, etc. Community-based design in cultural heritage projects can be an enriching and valuable process [2].

Location-based games (LBGs) for cultural heritage aim to convey stories and knowledge about cultural heritage via various playful and engaging design patterns, such as storytelling, role-playing, and treasure-hunts [3]. They are evolving into a game genre with a unique combination of features [4]:

- They are concerned with the creation of awareness and learning about the heritage of various cultural sites, such as GLAM (galleries, libraries, archives, museums), archaeological sites, cities, or settlements of important heritage, etc.
- Gameplay is interwoven with multifarious cultural content: narrative, characters, media, photographs, 3D models, challenges, hints, rewards, etc.
- Cultural heritage content must be reviewed by heritage experts.
- A mobile game for cultural heritage must allow players (visitors of a heritage site) to observe and explore the place at their own pace.
- Players are expected to be pairs or small groups—people rarely visit cultural sites alone.

The design of mobile LBGs for cultural heritage presents numerous challenges that must be addressed in close co-operation with local communities, cultural heritage professionals, and end-users (visitors of a cultural site), such as:

- The locations or points of interest (POI) that can be included in the game must be related to landmarks, monuments, and associated facts or stories about local cultural heritage to afford contextual learning and sense-making.
- Documentation about local heritage may include books, newspaper articles, photographs, testimonies, music, songs, etc., that can be provided by the local community and professionals to allow for culturally accurate and valid content.
- Various social, economic, political, and technological conditions affect the evolution of local heritage in ways that may be better told to the design team by those who have rigorously studied or experienced them.
- There are often many intangible aspects of local heritage [5] such as oral traditions, social practices and conventions, knowledge and practices concerning local nature and climate, and skills to produce traditional crafts that must be incorporated into the game.
- The cultural content must be curated and validated in close co-operation with local communities and cultural heritage professionals.
- Last but not least, the game must be played and tested in the field with visitors (end-users), heritage professionals, and the community, all of whom may bring a different perspective to some extent.

This paper presents an approach and methods for the participatory co-design of location-based mobile games that promote awareness and learning about the (tangible and intangible) cultural heritage of craftsmanship and artisanal technology. The approach and methods are based on the design thinking process and concern a 'suite' or family of mobile games for a museum network which have been developed in terms of a long-term project with numerous participatory activities (field visits, online prototyping, field playtesting, and field studies) from sensitization to implementation.

The paper is structured as follows: Section 2 presents related work in terms of co-design in cultural heritage in general, and in LBGs for cultural heritage in particular. Section 3 briefly presents the Mouseion Topos project, in the context of which this work has been carried out. Section 4 presents the participatory design activities followed for the development of mobile games. These are mapped onto the design thinking process, which was followed throughout the project. For each design activity, we report and reflect on participants, methods, and results. Section 5 discusses several issues of participation and co-design that were realized in the overall development of mobile games. Section 6 presents the summary and conclusion.

2. On the Context of This Work: The Mouseion Topos Project

The mobile game design and development has been carried out in terms of the Mouseion Topos project [6] which is a collaborative R&D project with the aim of promoting the cultural heritage of Aegean islands' craftsmanship through actions of digitization, development of interactive systems, and sustainability (Figure 1). Digitization involves actions of digital documentation, the preservation of tangible artifacts mainly found in local museums (exhibits), as well as architectural heritage [7]. Development of interactive

systems involves kinesthetic installations and, more importantly for this paper, mobile learning games that connect three museums of the Aegean with the nearby settlements:

- In Tinos Island and the settlement of Pyrgos, the Museum of Marble Crafts presents Tinian Marble Craftmanship [8]: the technology of marble, which holds a particular place in Greek architecture and art, through the meshing of tools and techniques used in working marble with the social and economic context.
- In Lesvos island and the settlement of Aghia Paraskevi, the Museum of Industrial Olive Production (olive oil is at the heart of the Mediterranean diet [9]) presents the industrial heritage of the olive oil sector and incorporates it into the broader architectural, social, and cultural context of the late 18th century.
- In Chios island, the Mastic Museum presents the production history of the mastic tree's cultivation [10] and the processing of its resin, which it integrates into the cultural landscape of Chios.

These museums are part of a broader network of nine museums (PIOP museum network [11]) that support the preservation and showcasing of Greece's cultural heritage, with an emphasis on its artisanal and industrial technology. Thus, these mobile games are about a network of museums. They share common system design and gameplay but have different visual identities, media, content, and graphics inspired by local context and heritage.

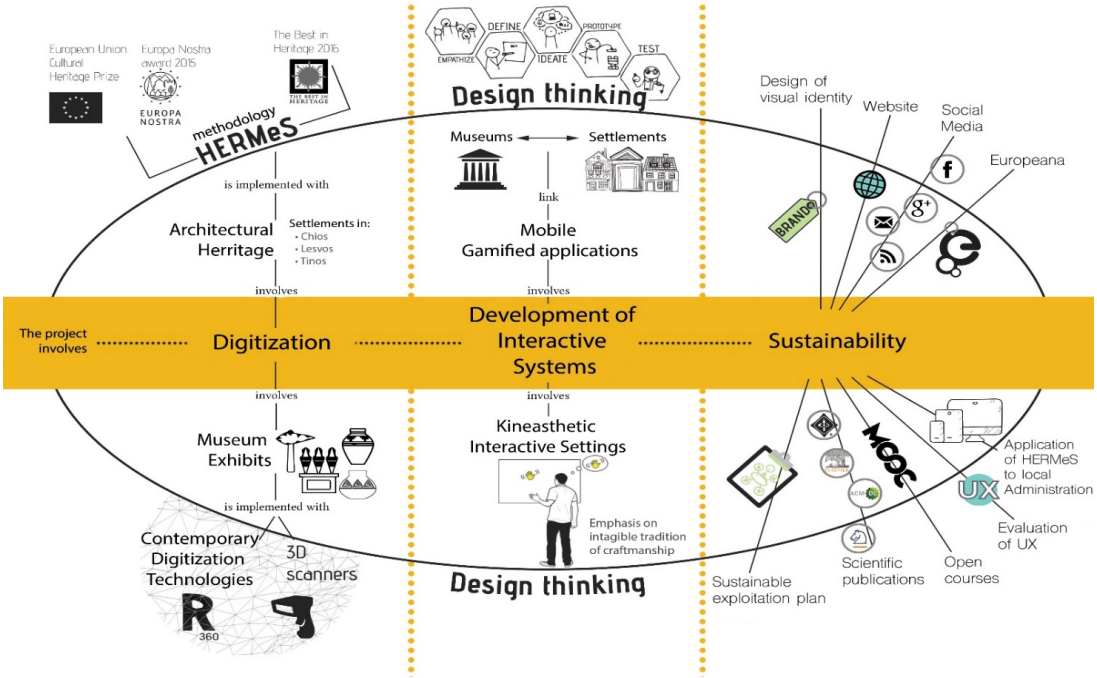

Figure 1. Concept model of the Mouseion Topos project.

3. Related Work: Co-Design in Cultural Heritage and Location-Based Games

3.1. Background on Co-Design and Participatory Design

Co-design is an approach or movement that draws on relevant approaches, such as participatory design, collaborative design, and user-centered design. Participatory design [12] has its roots in the demand for community (or labor) participation in public (or corporate) management. It includes methods mainly from the fields of action research and sociotechnical design and emphasizes the role of stakeholders such as citizens, employees, public bodies, customers, and end-users in decision making. Collaborative design [13] has its roots in complex product design engineering practice (e.g., automation, mechanical engineering, etc.), and emphasizes closely coupled, synchronous, intense co-operation among designers who put together their skills and expertise to creatively produce concept proposals or engineering solutions to design problems [14]. User-centered design

(UCD) [15] is a design philosophy in which users are involved throughout the research and development process, emphasizing empirical research and evaluation activities.

Co-design encourages joint design activity among end-users and designers aimed at the co-creation or production of artifacts or information that may be directly or indirectly incorporated into the final product [16]. These productions can reveal, implicitly or explicitly, tacit knowledge, values, and preferences about their anticipated user experience. According to [17], design activity of products, systems, or services is essentially about user experience, which may be revealed not only by what people *say* (e.g., via interview methods), or *do* (e.g., via observation or self-reporting methods), but also by what people *make* in productive co-design activities that have been planned and prepared by professional designers. Co-design is often carried out with co-design toolkits [18], i.e., a set of paper-based or tangible artifacts that are used, modified, or articulated by participants and may be studied at a later stage by the design team to reveal aspects of the UX. Co-design toolkits are common in some cases of co-design (for example with/for children [19]), but they are not common in cultural heritage projects where more participatory methods are employed, such as co-design workshops.

Over the last few years, co-design has often been referred to in a broader sense than co-creation activities and includes methods of participatory sensitization and decision- and sense-making [20]. Thus, it may also refer to creative methods of talking about user experiences (e.g., via storytelling [21] and workplace walkthroughs [22]) or doing (e.g., role-play and bodystorming [23]). Additionally, not only end-users may be involved in co-design; other stakeholders are often invited to participate in the co-design activities [24]. Last but not least, the importance of long-term co-design has been acknowledged in collaborative projects [25].

3.2. Participatory Design and Co-Design in Location-Based Games for Cultural Heritage

Participatory design and co-design activity in games for cultural heritage often involves children [26–28]. In these cases, the aim is to develop serious games played from a personal computer or the web, and not LBGs. There are not many approaches to co-design with children for mobile games, possibly since location and context matter the most, and an approach to inquiry about these with children would not suffice. Visiting a museum is a social experience and people often come in small groups, such as friends, families, tourists, etc. [29]. The involvement of families and groups of friends in co-design activity is again not common for the case of interactive technologies for cultural heritage, and these groups often provide input with participatory user research methods.

Location-based games for cultural heritage are a game genre with a unique combination of features [4]. They are played at various cultural sites such as GLAM (galleries, libraries, archives, museums), archaeological sites, cities, or settlements of important heritage, etc. Gameplay is interwoven with multifarious cultural content: narrative, characters, media, photographs, 3D models, challenges, hints, rewards, etc. Cultural heritage content must be reviewed by heritage experts. A mobile game for cultural heritage must allow players (visitors of a heritage site) to observe and explore the place at their own pace. Players are expected to be in pairs or small groups since people rarely visit cultural sites alone.

Earlier LBGs include the works of [30,31]. These works do not explicitly describe methods for involving cultural heritage professionals in the design process, but they indicate the active participation of users in the design process as an item of future research, i.e., "for future research, it is suggested that the effects of game-based learning when pupils not only play the game but are also involved in the creation of the game". Later work in mobile LBGs for cultural heritage often emphasizes important technical challenges such as the work of [32], that makes use of Beacon sensors [33] for outdoor navigation, or the works of [34,35] that apply augmented reality technology for mobile games in archaeological sites.

There are a few cases of co-design and participatory design of LBGs for cultural heritage, which are summarized in Table 1. These cases present high variability in terms

of the methodology/process, the methods employed, co-design participants, and type of project (duration, game genre, etc.).

Bowser et al. (2013) [36] present PLACE, an iterative mixed-fidelity approach to Prototyping Location, Activities, Collective experience, and Experience over time in LBGs. PLACE consists of six design principles: start small and scale up the fidelity, treat participants as co-designers, test in a representative space, focus on activities more than interfaces, respect authentic social experience, and represent time authentically. PLACE was employed in the design of 'Floracaching', a geocaching game for citizen science. Applying PLACE requires a series of incremental design workshops with experts (plant experts), designers, and developers who co-operatively prototype mixed fidelity prototypes. For each workshop, the issues of location, activities, experience, and experience over time are revisited among design participants.

Luiro et al. (2019) [37] present the co-design approach of a LBG about local history. The approach involved a field trip to the location (the town of Kemijärvi, Northern Finland), storytelling design, character design, and field testing. Co-design participants included a local travel agency, local museum staff, and a historian. The content is about the town's history in the 1920s. This approach is similar to ours in the sense that it involves local experts in various stages of the design process; however, the design methods and results are not discussed in detail.

Jones and Papangelis (2019) [38] present the activity of board games as a method to simulate the gameplay of a mobile LBG in the course of game design. Board games are played by potential users who interact with each other under the supervision of a game master. During board game play, the players review the game and provide various types of feedback that is recorded and considered for the design of the LBG. The board game may be redesigned and played again to test design improvements. This work did not include cultural heritage experts to validate stories, content, or context and this would be an important improvement. The games have been developed and tested in the field. A similar approach was also followed in [39], where the iterative process of paper prototyping using a board game was employed to co-design a location-based mobile application with potential end users that aimed to motivate user reflection on historical topics about migration.

Slingerland et al. (2020) [40] have conducted co-creation workshops and field playtesting to design location-based activities that can challenge citizens to explore their neighborhood in playful new ways. Co-creation workshops involved the inhabitants of the neighborhood in diverge–converge techniques about game design, challenges, and later in field playtesting with the aim of collecting insights on the game. Previous mobile game design approaches based on workshops include the MuseUs mobile game [41] in which players are invited to create their own personal exposition of exhibits during a museum visit.

These approaches to the co-design of mobile games for cultural heritage present specific tools or techniques that require contextual preparation and experienced moderation to produce useful design artifacts. Additionally, they emphasize joint co-creation among designers, users, and other stakeholders. Nevertheless, they do not present a holistic, 'from start to end', design process to engage end-users and cultural heritage experts in co-design activities over the course of a long-term project. In addition, it is not clear how particular techniques such as board games, gameplay experiences, and workshops might be re-used or adapted to similar contexts, e.g., in the case of a family of mobile games.

The work presented in this paper differs from previous approaches in a number of dimensions: (a) it is about the case of a long-term project with many participatory activities (such as field visits, online prototyping, field playtesting, and field studies) from sensitization to implementation; (b) it is concerned with the co-design of a 'suite' or family of LBGs of a museum network with a common general theme (intangible heritage of artisanal technology and craftsmanship); (c) it presents the design of transferable user experience (UX) for mobile games that have common conceptual design refined to the specifics of each case; and (d) it applies a common generic approach, based on the thinking process, in different cultural sites.

Table 1. Summary of co-design and participatory design approaches for location-based games for cultural heritage.

Citation	LBG Genre (s)	Cultural Heritage	Project Duration	Methodology or Process	Phase(s)	Method(s)	Participant Group(s)	Product
Bowser et al. (2013) [36]	Geocaching	Natural heritage (local flora), citizen science	Short (iterative sessions)	PLACE (Prototyping, Location, Activities, Collective Experience)	Prototype	Iterative prototyping from low to high fidelity	Players	One LBG.
Luiro et al. (2019) [37]	Exploratory learning, storytelling	Local history	Unspecified	Unspecified	Empathize, ideate, test	Field trip, narrative design, character design, field test	Local travel agencies, museum staff, art historian	One LBG.
Slingerland et al. (2020) [40]	Exploratory learning	Neighbourhood stories	Short (iterative workshops, two weeks)	Unspecified	Define, ideate, test	Co-creation workshops, field playtesting	Players (neighbours)	One LBG.
Jones and Papangelis (2020)	Storytelling, treasure hunt	Location—based game; cultural heritage (urban history)	Short (three co-creation sessions)	Unspecified	Define, ideate	Board game	Students (as potential players)	Two LBGs for two cities (different UX).
This paper:	Role playing, storytelling, tresure hunt	Industrial heritage (tangible and intangible)	Long (over two years)	Design thinking process	Empathize, define, ideate, prototype, test, implement	Field visits, workshops, laboratory user testing, experts' field playtesting, field studies	User groups, local community, peers (designers, developers)	Three LBGs for three cultural sites, transferable UX.

4. Participatory Design Based on Design Thinking Process: Participants, Methods, and Results

In the context of the development of the Mouseion Topos project, we organized the participation of cultural heritage experts and users in various co-design or participatory design activities, mapping them onto the phases of the design thinking process. Design thinking was proposed in the early 1990s by David Kelley and Tim Brown of IDEO as an encapsulation of several methods and ideas into a single unified concept [42]. It is a mindset that promotes the co-operation of designers, users, and other stakeholders in joint learning and creative activities, and also a process to achieve these. According to the N/Ng (Nielsen/Norman group) [43], the design thinking process comprises of 6 distinct phases:

- Empathize: conduct contextual research to gain knowledge about users and their experience.
- Define: identify user needs and project goals based on user experience research.
- Ideate: generate creative ideas for addressing user needs and meeting project goals.
- Prototype: create representations and artifacts that demonstrate the ideas in practice and test quickly and internally.
- Test: show prototype(s) to users and gather feedback for improvements.
- Implement: refine, publish, and release the product, system, or service and ensure that it reaches the intended users and groups.

We have adopted and refined various methods, principles, and resources that were appropriate at each phase of the process. These methods combine joint activities (field visits, content authoring, field playtesting, or studies) in the research and evaluation phases of the project, along with design review activities (brief/MDA, concept) by local experts and users. More specifically, we co-operated with various experts and users, who can be classified into the following groups:

- Cultural heritage professionals: these were the museum network research staff with various backgrounds (archaeology, museology, project management), museum curators, and museum staff including local administration and guides.
- Community: these were citizens or inhabitants of the settlements, local educators and pupils, local heritage experts, local scientific advisors of the museums of various backgrounds (e.g., folklorists, researchers on mastic applications), local craftsmen, and producers. Notably, museum staff were also members of the local community.
- Visitors of the museum and the settlement: mainly tourists, pupils, and educators during school visits.
- Designers: interaction and UX designers, software developers, and HCI researchers.

In Figure 2 we present the design thinking process of mobile games for cultural heritage emphasizing participant groups, methods, and results. We report on method selection, application, main results, reflections, and lessons learnt in the remainder of this section.

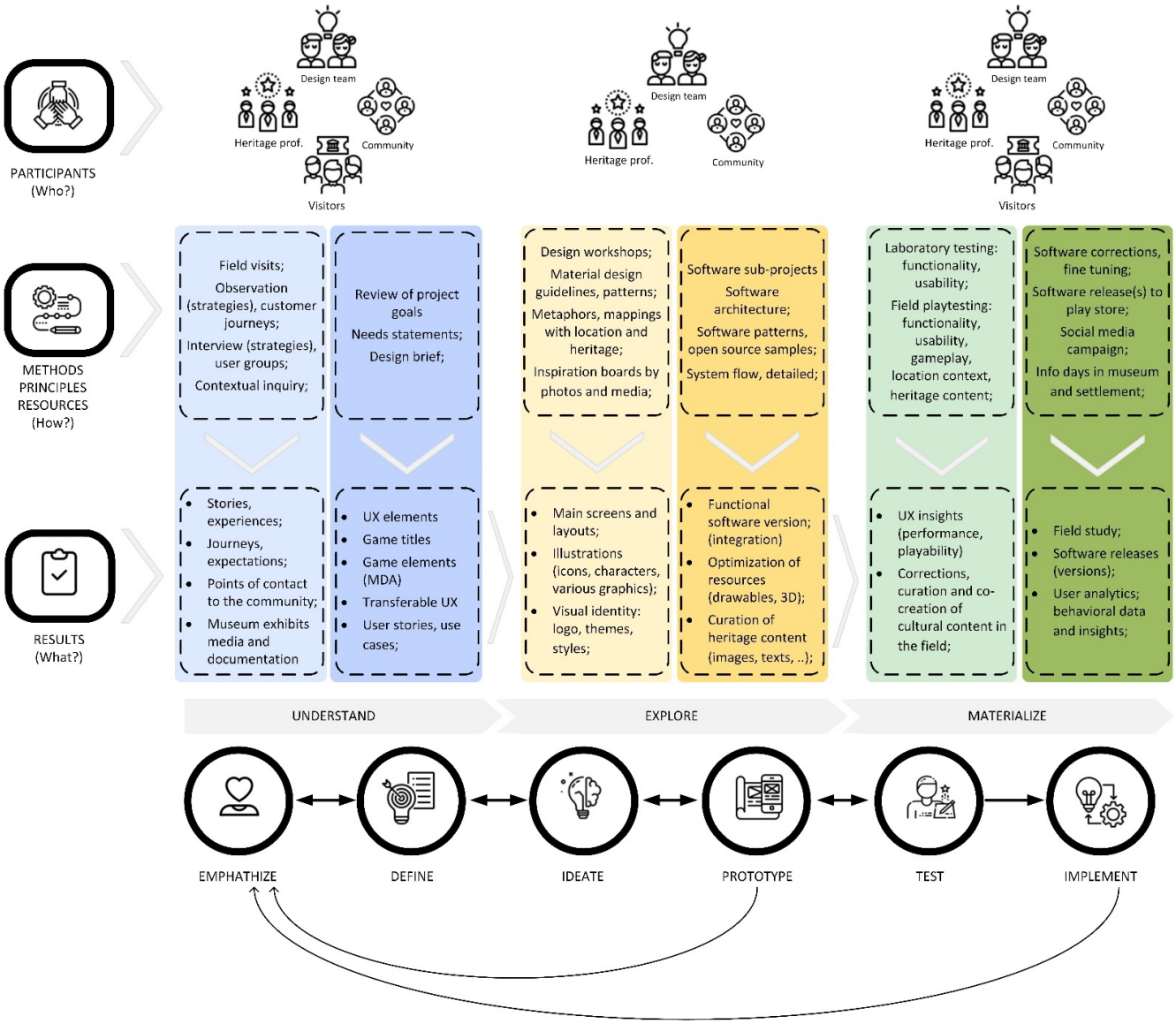

Figure 2. Illustration of main participant groups, methods, and results of participatory development and co-design of mobile games for cultural heritage.

4.1. Empathizing with People, Location, Context, and Heritage

4.1.1. Methods

The first stage of the process is to empathize with the people, the context, and the heritage. The main method employed for that purpose was **field visits**. At the start of the project, one field visit with the whole of the design team was conducted for each museum and settlement. Throughout the duration of the project, other field visits also took place with fewer design team members. The first field visits were most important because they actually initiated the project. Each one lasted 3 days in total. Each day was fast-paced with an agenda of various participatory UX research activities: observation, interview, and contextual inquiries with the participation of the local community, heritage professionals, and visitors of the museum and the settlement. Each field visit had the following general plan as outlined in the four paragraphs below.

Museum/settlement guided tour. The guided tour in the museum was one of the first activities of each field visit. It was conducted by the local museum director and staff, the research personnel of the museum, and the design team. The guided tour in the settlement was conducted by selected members of the community administration: a major, the ex-

major, and a member of the local administration, all of whom were heavily involved in the creation and operation of the local museums as well.

Observations of visitors in the museum/settlement: We adopted a number of **observation strategies** to learn about visitors, local context, and heritage, especially those of: 'the fly on the wall', i.e., discrete and remote observation from selected viewpoints; and 'shadowing', i.e., discrete following of visitors to get a sense of their journey. Observation was a continuous process that occurred in the intervals of meetings and interviews. During observation we took various notes, several photos, and videos that were put into a shared repository for further study. Several of these were re-used in mobile app design and development.

Interviews with community members, heritage professionals, and visitors: We interviewed a range of people in each field visit. **Interviews** were held in the most appropriate place to allow for cues about heritage. For example, we interviewed former workers and masters of olive oil production in the main hall of the museum (former olive press) where the action took place, and the machinery was switched on to allow for schematic and bodily illustration of the work. In the case of mastic heritage, we visited mastic fields and talked to mastic producers about the cultivation process. We also visited the Chios gum mastic growers' association [44] to learn more about current research and applications of the mastic resin. In the case of Tinian marble crafts, we visited two marble sculptors in their workshops, where we talked with them as they were working and also had the chance to experience the tools and processes. We also talked with the local scientific advisor of the museum (folklorist) who provided us with hand-written notes of a tour and game that he had developed for school visits at the settlement of Pyrgos.

Contextual inquiry with community members, heritage professionals, and museum staff: We conducted **contextual inquiry** sessions with museum staff to learn about their everyday work with an emphasis on tacit knowledge, possible breakdowns, and concerns that might be addressed by the project. These were mainly related to issues about ensuring that the museum is up and running according to schedule and providing quality information and services to various kinds of visitors.

4.1.2. Results and Reflection

Field visits produced a wealth of insights and possibilities about the design of mobile LBGs (Figure 3). We collected several **stories and experiences** about cultural heritage from the local community and the museums while also highlighting visitor **journeys** and identifying **expectations** from their visits.

Field visits were an exciting sensitization and learning experience for the design team as well. The motivation of the team was strengthened after the field visits. We also established sub-teams to further work on aspects of the mobile game design. The participatory approach was also appreciated by the local community and heritage professionals. This laid the ground for further contacts and collaboration throughout the duration of the project. Thus, we established several **points of contact** with external experts and user groups.

An important result from the field visits related to the **resources and materials** obtained. We took several hundred photographs and videos from places in the settlements, museum exhibits, spaces, and visitors and their experiences. We identified possibilities of cultural content for the mobile game based on museum exhibits, landmarks, and monuments in settlements, as well as stories, and facts about heritage told by the local community and presented at the museums. We were also provided with valuable resources, including books about the history of settlements, books about aspects of cultural heritage (such as about marble crafts tools and techniques [45]), and museum guides.

Figure 3. Photographs from field visits. Left, up: Tinos, museum of marble crafts; observation of two pupils who are watching a video in front of tools and marbles in the quarry section. Left, down: Tinos, settlement; a member of the design team is learning to apply marble sculpting tools in a workshop. Center, up: Lesvos, museum; a master of olive oil production explains the works to the design team. Center, down: Lesvos, settlement; the design team on their way to the town hall, one of the historic buildings in the settlement. Right, up: Chios, mastic museum; guided tour. Right, down: Chios, settlement; a member of the design team taking video notes.

4.2. (Re-) Defining and Reviewing Goals, Needs, and Elements of Mobile Games

4.2.1. Methods

During the second stage of the process, the design team worked in co-operation with cultural heritage professionals on the basis of insights from field visits. After several discussions and iterations, we produced: (a) needs statements concerning user groups of visitors, (b) a refined set of goals for the development of the mobile games, and (c) a condensed description of the games and design brief.

Needs statements were about the anticipated user experience of visitors. For example, in the case of the heritage of marble crafts, some of these statements were: "I want to learn about/significant works of marble crafts/important marble sculptors/the story of the life of Giannoulis Chalepas", and, "I would like to experience the use of tools to create a work of marble". In the case of mastic heritage, some statements were: "I want to know about uses and applications of mastic in cosmetics", and, "I would like to use tools of mastic cultivation". Similar statements were also about industrial olive oil production, for example, "I would like to understand the process of producing oil from olives and the use of the machinery".

Subsequently, the **goals** of the mobile games were refined in order to include insights from field visits. Thus, we specified that the game would emphasize exploratory learning, storytelling, role-playing, and rewards that users could experience (in augmented reality). Exploratory learning is generally about the activities of observation and exploration, which happen naturally to all people, especially in previously unknown situations [46]. These fit ideally with mobile games for cultural heritage since numerous visitors to the cultural site will be visiting the museum and the settlement for the first time. Storytelling would interweave stories about heritage with game missions and challenges to enhance player engagement and sense-making. Role-playing, i.e., the assuming of a role by visitors in

gameplay, can further engage them in exploring the museum and the settlement with the company of the mobile game. In all three games, the player assumed the role of an apprentice who had to fulfill learning missions and challenges to level-up and become a master of heritage. Last, but not least, we decided to introduce rewards to players of the game in the form of tools related to cultural heritage in augmented reality, so that the players would 'obtain' them in digital form (3D), and see them in the space (via their mobile phone camera).

We also constructed the storyline of the game in **'design brief' documents** that guided the design team to further analysis of the constituting elements of the mobile games. For each game, the main points of the design brief were as follows:

- The goal of each mobile game is to help the player explore the museum and the settlement in order to learn about (become 'master' of) various aspects (history, social-economic conditions, everyday use, people, landmarks, tools, machinery, etc.) of local heritage (olive oil production / mastic / marble crafts).
- Through the game, the player is guided to specific locations where they can answer learning challenges of various types. These locations are grouped geographically and semantically into learning missions with appropriate names.
- Regarding role-playing, the player helps a digital character who is an apprentice (at the community olive oil press / at the mastic field / at the marble crafts workshop) and can level-up to a master. Also, another digital character plays the role of a master who poses questions and can also provide contextual (location-specific) help.
- When the player completes a mission (group of challenges), they then receive a reward in the form of a digital 3D tool that can be viewed in augmented reality.
- The player earns experience points, earns experience levels, and can view their profile that records their learning progress.

4.2.2. Results and Reflection

During meetings and reflections on the field visits and resources, it was quickly realized that all mobile games should have a **common system and gameplay design**. All games are part of the same project, as well as about a network of museums. These museums present craftsmanship and artisanal technology use that was learned from the older generation to the new through a 'master-apprentice' model. They also include several elements of tangible and intangible culture that are bonded together (e.g., specific tools with processes or skills, specific works carried out with appropriate and traditional clothes, specific products connected to uses of everyday life in various activities) and are strongly linked to the local communities who have been the living carriers of their heritage for several generations. On the other hand, the mobile games should have several distinguishable elements about narrative, visual identity, media, content, and graphics that would reflect local context and heritage. Therefore, the design of the user experience should be transferable across all three mobile games [47]. The three mobile apps have similar mobile app names to reflect that they are part of the same project but concern different islands. They also have different game titles that reflect the heritage and the challenge (Table 2).

Table 2. Mobile app names (play store) and game titles.

Name of the Mobile App (Google Play)	Mouseion Topos #Tinos	Mouseion Topos #Lesvos	Mouseion Topos #Chios
Game title	Explore the Marble Town	People's Machine	Mastic and Mastichochora

In order to define the main elements of the mobile games, we adopted the **MDA (Mechanics, Dynamics, Aesthetics)** model [48]. These elements are summarized in Table 3. Mechanics are essentially the rules of the game at the level of data representation and algorithms. In our games, the main mechanics are missions, challenges, player levels, expe-

rience points, player inventory (or toolbox), hints, digital characters, maps, and rewards. Dynamics refers to the "behavior" of the elements of engineering, at the level of interaction with the player. Dynamics update some of the mechanics of the game (e.g., experience points, player level, missions and challenges completed, etc.) with respect to user location and provided answers to challenges. Aesthetics refers to the desired emotional responses of the player while engaging in the game. Among others, the following aesthetics were considered suitable for the mobile games: discovery, learning, competence, storytelling, and engagement.

Table 3. Mechanics, Dynamics, and Aesthetics of the Mobile Games.

Mechanics *Components of the Game*	**Dynamics** *Run-Time Behavior*	**Aesthetics** *Desirable Responses*
Experience Points (XPs): Points gained after completing a challenge.	+50 XPs if successful, or +10 if unsuccessful.	Sense of accomplishment, competence.
Missions: Semantically and spatially related groups of challenges.	Mission is completed when all associated challenges are undertaken.	Discovery, learning, sensitization to CH.
Challenges: Questions about CH, to be discovered in settlement/museum.	Challenge is completed when answered (successfully or not).	Discovery, learning, sensitization to CH.
Tool: A tangible artifact, most often a tool of a worker, that is an exhibit of the museum.	It is earned when the player completes a mission.	Discovery, 'Wow factor!'.
Toolbox or inventory: A set of tools.	When the inventory is full, the game ends and the player can view all tools in 3D.	Sense of accomplishment.
Virtual characters: A novice that the player must help to learn about CH. An expert who sets challenges; provides hints and rewards.	The novice character appears in reward cards and the user profile. The expert character appears to provide hints or help.	Plausibility, engagement.
Narratives: Short texts on stories and knowledge about CH.	They unfold in various user actions: asking for hints, under rewards (more information), in notification cards, in mission introductory cards.	Storytelling, engagement.
Hints: Short texts to help the player identify the location of the answer, or about framing the context.	They appear when the player reads a challenge and taps onto the expert character.	Help, learning.
Maps: A graphic map about missions. An actual map about challenges (of a mission).	User location can be enabled The color of push points indicated a challenge has been undertaken.	Learning, wayfinding.
Player levels: Three levels: novice, helper, expert.	Player levels up after gaining 1/3 of all experience points.	Sense of accomplishment, competence.
Rewards: Challenge reward: a card with a message and more. Mission reward: a challenge reward with a tool earned.	Appears after the completion (successful or not) of a challenge or a mission.	Sense of accomplishment, learning.

4.3. Generating Ideas for Visuals with References to Heritage

4.3.1. Methods, Principles, and Resources

To organize idea generation and production, we conducted several design workshops and meetings. These were generally scheduled every two weeks and were kept relatively short in duration (between one to two hours maximum). They were held online to accommodate remote participants who were located in several geographical locations in Greece. We used various conferencing and collaboration tools, especially Zoom [49] and Figma [50]. Depending on the goals of each workshop or meeting, the participants included members of the design team and, sometimes, cultural heritage professionals and members of the local community.

The aim of **design workshops** was to come up with ideas and—to the extent possible—visual illustrations or sketches about specific design issues. While each workshop aimed to obtain concrete and agreed results, this was not always possible within the time frame of the online meetings. In those cases, the design team was left to produce finer representations at their convenience, until the next meeting. Design review and feedback was the main goal of **design meetings**, which did not focus on production of new artifacts, but on discussion and review of aspects of the produced visuals. Therefore, design workshops and meetings were usually held interchangeably.

The design of the mobile games was guided by the **Material Design guidelines** [51], which is an adaptable system of guidelines, components, and tools that supports best practices of user interface design in native Android development applications. These are also supported by open-source code patterns and samples that can be adapted by UX designers and software developers.

In addition, we made a conscious effort to produce designs that were strongly inspired, informed, and influenced by **metaphors** [52] from heritage and local context, and **mappings** between the real world and the designed system [53]. Metaphors or mappings were about form, terminology, tangible artifacts of heritage (such as tools, clothes, etc.), and stories or narratives. Respective examples of metaphors can be observed in the design of the games (e.g., screen shots in subsequent Figure 5 and later in Figure 8), and include:

- The shape (form) of olive oil drops and mastic resins is conveyed in the graphical illustration of the (abstract) concepts of a mission on the mission map of the mobile games about industrial oil production heritage and mastic heritage, respectively.
- Local terminology is used throughout the game and concerns tasks, tools, clothes, etc., which were often the objects of player challenges, as well as the 'levels' of workers and masters.
- Tangible artifacts were selected, and designed or scanned into 3D, to be provided as rewards to players.
- Several stories or narratives were embedded in player character guidance, help, and 'learn more' (after a completion of a challenge) sections of the game.

4.3.2. Results and Reflection

During the ideation phase, we produced several visuals for the main concepts of the mobile games. Figure 4 presents the detailed design of some of the screens (including onboarding screen with digital character, missions map, challenges view (map and list)) for all three games. A few key visuals included:

- Icons about several concepts of the game: experience points, missions, challenges, type of challenge, and tools. These were common among all games.
- Mobile app logos: same design but different color palette for each game.
- Illustrations about several graphical elements: art tools, craft tools, and artisanal technology as well as digital characters; all of which were different for each game.
- Missions map illustrating landmarks of the settlement and each mission. It was graphical because challenges were not always spatially aligned (despite being semantically related for each mission). Notably, when the users would select to view a specific mission, they could see the actual map with locations of all challenges for the mission.

A principal result of the ideation phase was the design of wireframes and detailed screens of the mobile game. These were designed in the Figma online prototyping tool, and they were refined in several iterations. During this phase, the design of most significant screens was completed (Figure 5).

Ideation is the most creative and iterative phase of the design thinking process. To keep control of the process and present notable progress among workshops and meetings, we kept a relatively tight schedule for our meetings. We worked in several iterations of the core design and development team of the game, while also having fewer iterations with larger participation, including other team designers, project members, cultural heritage

professionals, and community members. These meetings were necessary to go through the outcomes and further ideate and validate several visual elements.

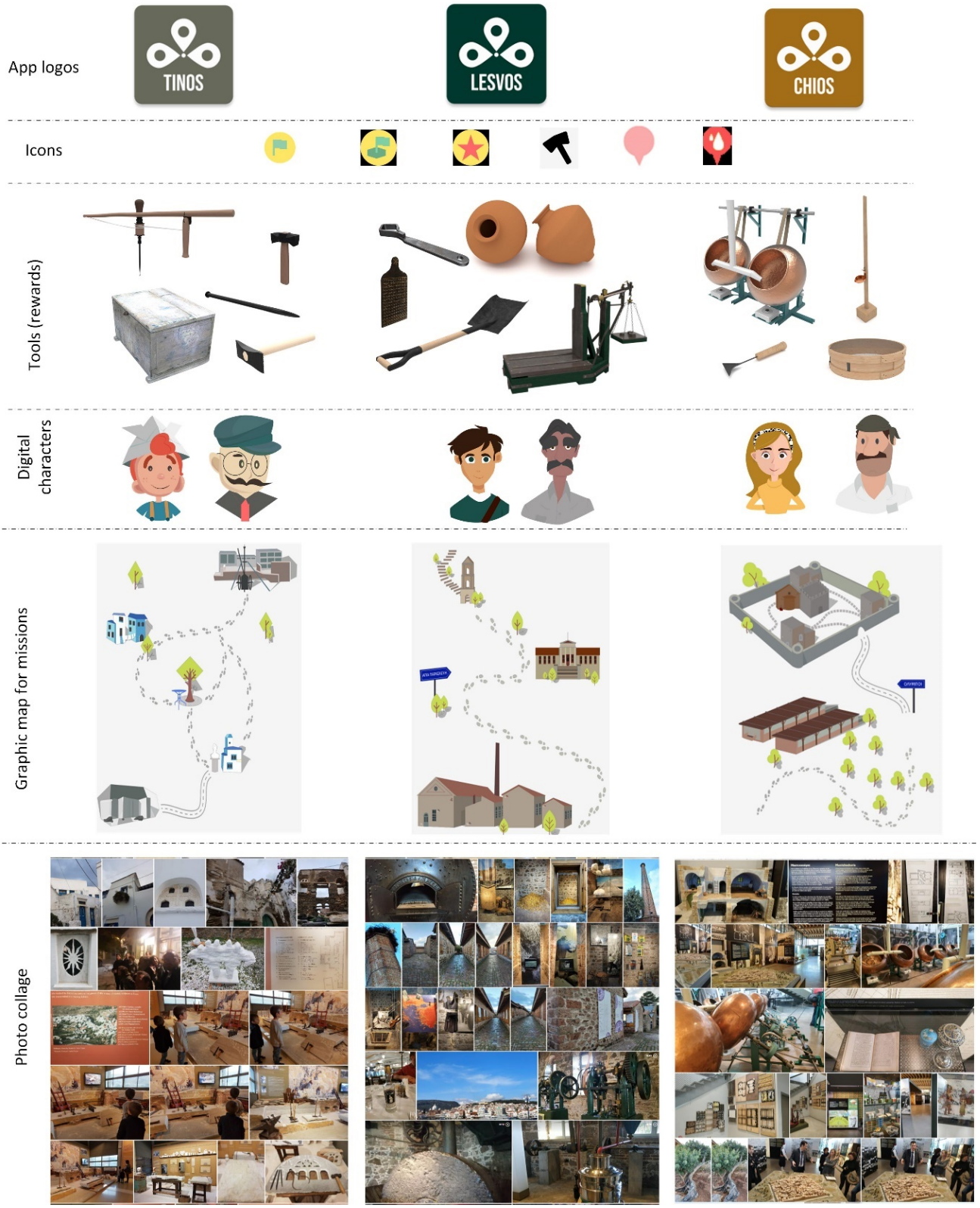

Figure 4. Visual elements produced at the ideation phase: app logos, icons, graphics for tools, mission maps; and photo collages used for inspiration.

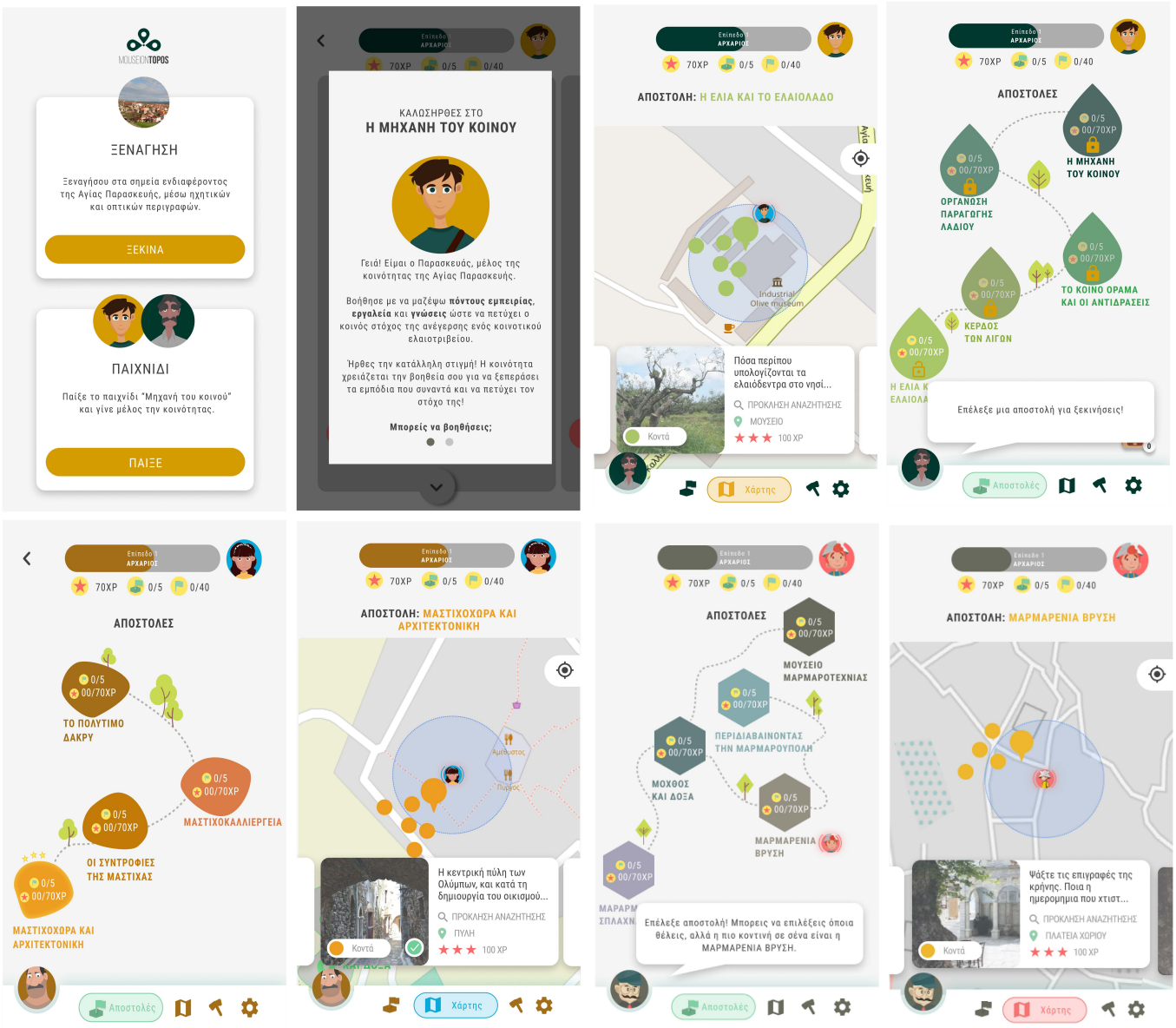

Figure 5. Detailed designs of some of the screens of the mobile games. Upper row: People's Machine game (Mouseion Topos #Lesvos). From left to right: 'Tour or Game' screen; onboarding with digital character; missions map; and challenges view (map and list). Lower row: First two screens are the missions map and challenges view of the Mastic and Mastichochora game (Mouseion Topos #Chios). Last two screens are the missions map and challenges view of the game Explore the Marble Town (Mouseion Topos #Tinos).

4.4. Prototyping Mobile Games for Cultural Heritage

4.4.1. Methods, Principles, Resources

The prototyping stage included several iterations ranging from reviewing the detailed screen designs from the Figma prototyping tool to software development in the Android Studio SDK. We also kept the software in three GitHub [54] repositories to collaboratively write code and share. We conducted three phases of prototyping:

- Software subprojects: Included basic use cases of the mobile game, such as onboarding, character help, missions map, challenges views, reward cards, and AR views. For some of the subprojects we experimented with open-source software. This phase lasted for almost four months.
- First integrated version: These were fully functional mobile games tested in the lab to eliminate bugs, and then in the field with expert playtesting (described in the next section).
- Release version: Several playability and usability issues were addressed in this stage. Additionally, more functionality was added, especially regarding mobile AR, and more animations.

In addition, in this phase we followed the Android Architectural Components framework [55] to define the main software functionality of the mobile games. The Android Architecture Components framework ensures that the software follows programming patterns that are compatible with other Android software libraries and is structured in a way that avoids boilerplate code and ensures data persistence and automated lifecycle management of a mobile app. Furthermore, during software development and integration, we developed other flows and diagrams about basic processes that should be supported in the mobile game.

Throughout the software development phase, the main results were shared through videos which were reviewed in meetings with designers. The main concern was that the design had to be implemented with a few differences in some use cases. Therefore, the designers would have to review software functionality and discuss whether this was acceptable.

4.4.2. Results and Reflection

Prototyping and software development eventually resulted in **functional mobile games**. These were tested extensively in the lab for functionality, usability, and cross-device operation. They were also reviewed by selected cultural heritage professionals and community members. But they were not close to being released yet, since they had not been tested in the field.

During the software development process, we experimented with new and contemporary features, especially concerning augmented reality. Thus, it was important to start early with software development to realize technological capabilities and possible risks. Another reason to start early with software experimentation and development is that one has to review, and possibly adapt and utilize, open-source software (patterns).

Another result of the testing phase was the refinement of the **software architecture** of the mobile games (Figure 6). This consists of the main software modules grouped in a layered system design that allows a modular software structure and adherence to modern programming patterns. The main components of the system architecture include:

- User interfaces: software that implements every visible aspect of the system and the interactions with users.
- View models: software that makes data available to all user interfaces and is responsible for propagating data changes caused by user actions downwards to the system database.
- Repository: this is an API (Application Program Interface) that is available to the view models for requesting data from the database.
- Database: This is a local database that holds all the data of the mobile game. It is built during the installation of the mobile game. It is available in two languages (English and Greek) and populates data from app resources.

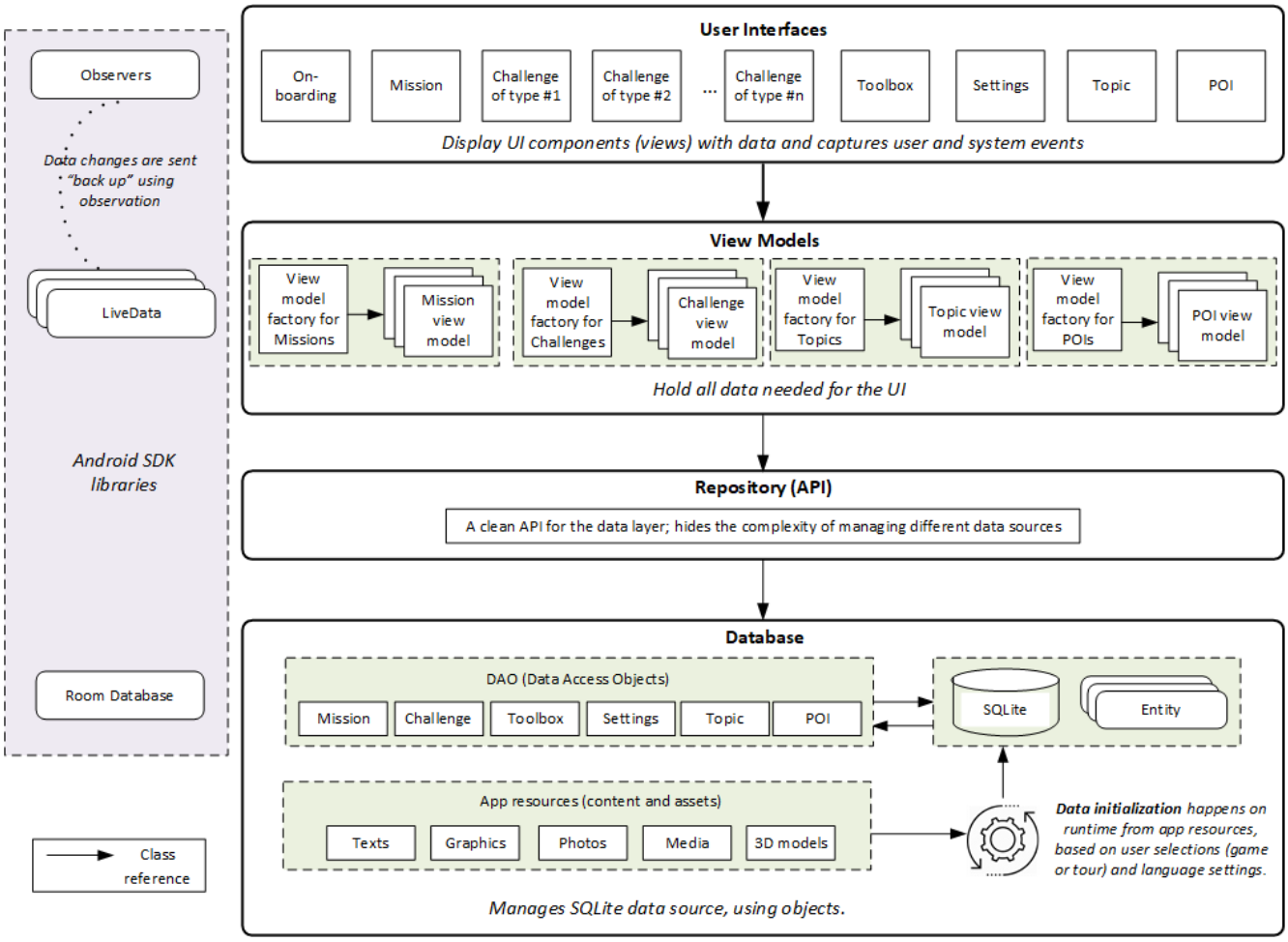

Figure 6. A common software architecture for mobile games, based on Android Architecture Components.

4.5. Testing in the Field with the Participation of the Community, Heritage Professionals and Visitors

4.5.1. Methods, Principles, and Resources

Mobile LBGs must be tested in the field to ensure that testing occurs in an authentic context of use with the participation of representative users in the actual location, place, and space. Despite having tested the games extensively in the lab for functionality and usability, we were still uncertain about many aspects of gameplay, such as how much time users would require to finish the game; if terminology was in accordance with museum and settlement signs; if navigational help was making sense for users in the museum or settlements; if the challenges were all valid from a heritage perspective; if we needed to add more learning challenges about heritage, and so on.

For the case of our mobile games, the 'field' was the museums and the settlements of the three Aegean islands. Testing in the field was not immediately possible due to the pandemic. It was planned as soon as museums opened to the public, but still there were very few visitors. On the other hand, we were also interested to see the views of the local community and heritage professionals on the mobile games. These groups have expert opinions on some aspects of the design, and they are also end-users and visitors of the museums. Thus, they may play the game to learn about particular challenges that they might not be aware about.

To conduct a thorough testing in the field, we constructed a method called **field playtesting with experts' constructive interaction** [4]. This is a qualitative testing method in which local 'experts', including cultural heritage professionals, representatives from the local community, and peers (i.e., interaction designers and software developers) play

the whole of the game co-operatively in pairs. Thus, the players are instructed to playtest the game in pairs, perform tasks together, and uncover design issues indirectly via their discussions and explanations to each other. Constructive interaction (or co-discovery learning) is a research protocol with psychological foundations (O'Mailey et al., 1984 [56]), and has been reported to produce increased and more relevant results in usability studies [57]. Additionally, it is a very natural way to conduct the field testing of mobile LBGs. During playtesting, interaction between evaluation researchers and players was minimal; however, researchers did keep notes (we have developed a coding scheme for convenience). The method resembles what people do when they visit cultural sites, i.e., they visit in pairs or small groups. Additionally, further findings arise from players' interactions with minimal researcher intervention; therefore, the method enhances ecological validity.

In field playtesting we placed emphasis on the whole experience of playing a game and on the playability of the game, which included issues of usability, functionality, gameplay, cultural content, and local context:

- Usability findings are about how easy it is for the players to make use of user interfaces and interactions.
- Functionality findings concern the technical quality of the game, e.g., smooth operation, no bugs or crashes, short loading times, etc.
- Gameplay findings are concerned with understanding game elements, rules, and dynamics (how these are updated and interact into a cohesive whole).
- Cultural Heritage Content findings concern the need to correct, add, create (new), or update content.
- Location context findings concern those related to information, indications, and guidelines that help the user understand if they are at the right location or are heading accurately towards it.

We conducted three playtesting activities, one for each museum and settlement, in which we employed cultural heritage professionals, local community heritage experts, and peer designers and developers.

In Tinos, at the museum of marble crafts and the settlement of Pyrgos, we tested the game 'Exploring the Marble Town'. The participants were a total of ten experts, with an average age of 41, of which four were women. Four of them were cultural heritage experts as well as local community representatives: the museum director, two museum staff, and a local heritage expert. The others were two game designers and developers, two interaction designers, one graphics and 3D content developer, and one expert from IT (Information Technology) and cultural heritage project management. The playtesting sessions took place during a two-day project meeting at the Museum of Marble Crafts.

In Lesvos, at the museum of industrial olive oil production at the settlement of Aghia Paraskevi, we tested the game 'People's Machine'. Fourteen experts were recruited in playtesting with an average age of 39, of which seven were women. Six of them were cultural heritage experts as well as local community members: a museum curator, the museum director, two museum staff, and two local heritage experts. Other experts were: four game designers and developers, two interaction designers, one graphics and 3D content developer, and one expert from IT (Information Technology) and CH project management.

In Chios, at the Mastic Museum and the settlement of Olympoi at Mastichochoria, we tested the game 'Mastic and Mastichochoria'. We employed twelve experts with an average age of 38, of which six were women. Six of them were cultural heritage experts as well as local community members: the museum curator, the museum director, two museum staff, and two local heritage experts. Other experts were: two game designers and developers, two interaction designers, one graphics developer, and one 3D content developer.

Each field playtesting activity lasted for two full days. In each day, we conducted playtesting sessions with two or three pairs of users. Each playtesting session lasted approximately two hours for each pair of players, including note taking. For the case of the game 'Mastic and Mastichochoria', we did not analytically record findings because we immediately realized that cultural content about the game (challenges) was largely not associated to specific places or exhibits, while accompanying narrations and help were not linked to the locations. Additionally, since Chios was the last museum visited, we had already identified several playtesting issues of more general nature that applied to this game as well. Therefore, we emphasized the detailed review of existing cultural content and the co-creation of new content for that game with all participants.

4.5.2. Results and Reflection

Field playtesting was an invaluable process for the development of the mobile games for two main reasons: (a) UX insights and identification of design improvements, and (b) correction, curation, and co-creation of cultural heritage content in the field.

Regarding **UX insights**, we first identified several **performance indicators** related to playing the games. Table 4 highlights performance indicators for two the of three games. For example, the average time to complete the game 'Exploring the Marble Town' was 107 min (54 min of gameplay, 53 min time in-between, e.g., walking, talking, etc.). This was much larger than the game 'People's Machine' (66 min total, 40 min gameplay, 26 min time in-between). This was anticipated, but it was not possible to safely estimate before playtesting in the field, i.e., the first game originally included considerably more challenges in the settlement (12 in the settlement, 6 in the museum) than the latter (5 in the settlement, 10 in the museum). This was also reflected in the distance covered in both games, which was more than double for the first game (3.3 km/1.4 km). All performance indicators were valuable data that were used to further enhance the UX of the games by introducing them in gameplay, e.g., to the reward system or to add indications or warnings.

UX insights mainly included several **playability findings** about the games that were classified into those about gameplay, usability, functionality, location context, and cultural heritage (CH) content (Figure 7). Gameplay issues were related to understanding the mechanics and dynamics of the game, e.g., about the player levels, experience points, what players would have to do to complete a mission, and so on. Usability issues were mostly of a general nature involving navigation, user guidance, and help, such as *"It is not perceived by users that the helper character icon can be clicked"* and *"Missions accomplished are not highlighted onto the mission map"*, etc. Functionality issues were about bugs identified for some devices as well as some device-specific installation problems. Several location-specific issues were valuably revealed through this process, such as: *"Some users are not sure if they are at the right spot to start looking for the answer (they wander around unnecessarily)"* and *"Some users cannot locate the answer, despite on the spot (they need to be provided with a guideline, e.g., read the sign)"*. Multiple insights were common among the games. For the second game, more issues of minor significance were identified, mostly related to cultural content issues.

Another important aspect of the field playtesting process was that it enabled **corrections, curation, and co-creation of cultural content in the field**. Firstly, we identified several findings that could be easily fixed, including several corrections to texts and narratives. Additionally, we identified some challenges that were not accompanied with the most appropriate or characteristic photographs. In those cases, it was also easy to take photos immediately and make notes appropriately. For some challenges, their geo-location had not been accurately marked on the map, which was also easily change to mark the exact spot. However, more importantly, cultural heritage professionals and local community heritage experts marked several challenges that did not convey an important takeaway about local heritage. Furthermore, they could easily propose alternatives or modifications to existing challenges. Therefore, co-creation of cultural content was performed in the field between playtesting with designers and cultural heritage experts in close co-operation.

Table 5 presents a summary of cultural content in product versions of the mobile games, before and after field playtesting.

Field playtesting is an empirical design review method which unfolds as experts experience the game, in contrast to typical design reviews or juries that examine presentations or demonstrations of artefacts or systems, possibly based on guidelines or heuristics. However, a larger and broader pool of experts is assumed (combining designers with cultural heritage professionals to allow breadth and depth of insights) than other expert review methods, e.g., heuristic evaluation by Nielsen [58]. It requires playtesting, a standard approach to game evaluation that emphasizes playability, i.e., a composite concept that includes (at least) aspects of gameplay, usability, and functionality [59].

Table 4. Performance indicators in field playtesting of the mobile games.

Performance Indicators	Mouseion Topos #Tinos Exploring the Marble Town	Mouseion Topos #Lesvos People's Machine
Game completion time	107 min	66 min
–Gameplay time	54 min	40 min
–Time in-between	53 min	26 min
Distance covered	3.3 Km	1.4 km
Time to complete a challenge	3 min	2.7 min
Experience points gained	790 (max 900)	670 (max 750)
Challenges not answered correctly	2.9 (total 18)	3 (all 15)
Challenge difficulty	4 h; 9 m; 5 e;	3 h; 8 m; 4 e;

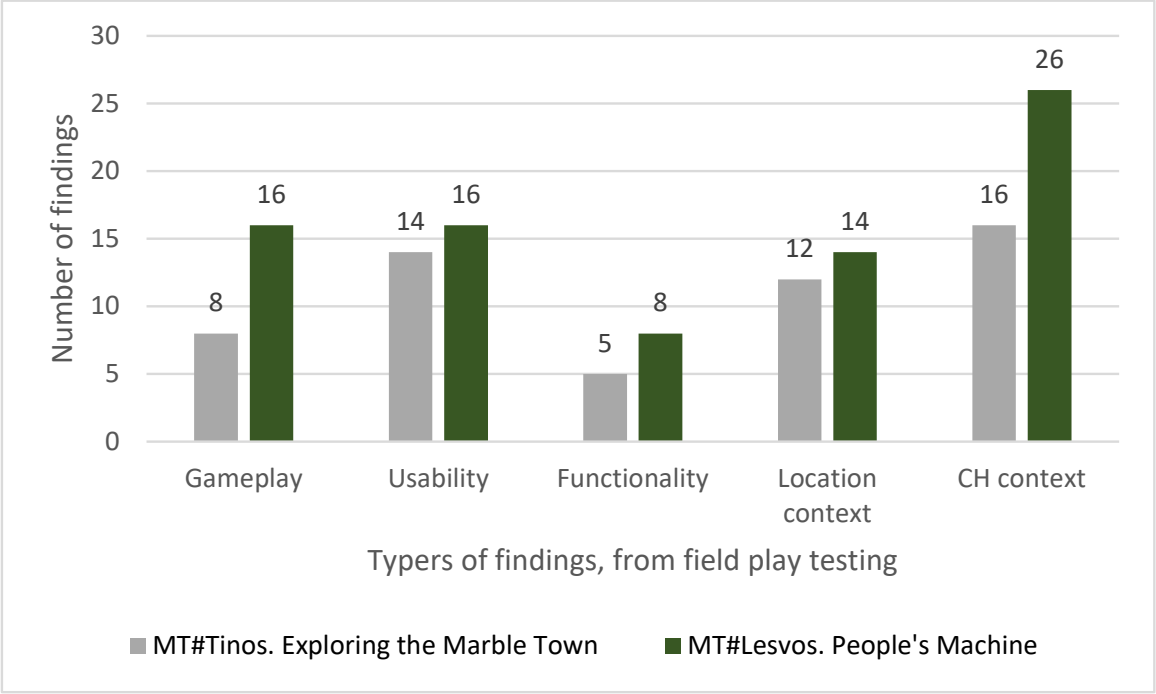

Figure 7. Overview of findings from field playtesting of the mobile games.

Table 5. Summary of cultural content in product versions of the mobile games (before and after field playtesting).

Mobile Game	Product Version	Missions	Challenges	Comments
Mouseion Topos #Tinos Exploring the Marble Town	Fully Functional prototype (before field playtesting)	5	18	• Corrections to almost all challenges. • Four (4) challenges were deleted. • Fourteen (14) challenges retained.
	End-product (after field playtesting)	5	23	• Nine (9) new challenges added.
Mouseion Topos #Lesvos People's Machine	Fully Functional prototype (before field playtesting)	4	15	• Corrections to almost all challenges. • Five (5) challenges deleted. • Ten (10) challenges retained.
	End-product (after field playtesting)	4	23	• Thirteen (13) new challenges added.
Mouseion Topos #Chios Mastic and Mastichochora	Fully Functional prototype (before field playtesting)	4	14	• Corrections to almost all challenges. • Seven (7) challenges deleted. • Seven (7) challenges retained.
	End-product (after field playtesting)	4	26	• Nineteen (19) new challenges added.

4.6. Implementation: Corrections, Release, Field Studies, and Dissemination

4.6.1. Methods and Resources

After field playtesting with experts, we consolidated all findings and authored the software to incorporate them. Screenshots of the mobile games are depicted in Figure 8. From usability and gameplay perspectives, numerous details had to be improved or corrected in texts, photographs, guidelines, location point coordinates of challenges, etc. From a UX design perspective, some important improvements from previous versions (Figure 5) included: removal of the bottom navigation bar, addition of the backpack in the main screen for collecting tools, enlargement of the digital character design so that they appear in full screen, and clearer indications of player progress (e.g., challenges taken). The games were then released on Google Play.

The public **release of the mobile games** was accompanied with a dissemination campaign. This was conducted in social media [60] with various posts and news about the final release of the mobile games. Additionally, the mobile games were presented in several online or live events (e.g., design exhibitions [61]). For these reasons promotional videos of the mobile games were also developed [62]. In addition, printed posters were also installed in the museum and the settlements (Figure 9) to inform visitors about the mobile games and present them with QR codes to download them.

4.6.2. Results and Reflection

Part of the dissemination activities was information days in the museums, in which we invited local community experts and schools (junior and senior high schools) to play the games. During the information days, we conducted **field studies** with pupils. We asked them to play the game alone or in pairs. We observed their gameplay and we remained available for any questions or clarifications. Participation was voluntary. The game was played mainly in the museum; not all schools could visit the settlements because of time restrictions. The participants for each field study were as follows:

- Tinos (Explore the Marble Town): 40 pupils; all 1st grade senior high school (15 years old).
- Lesvos (People's Machine): 84 pupils; all 3rd grade junior high school.
- Chios (Mastic Museum): 69 pupils; all 1st grade senior high school.

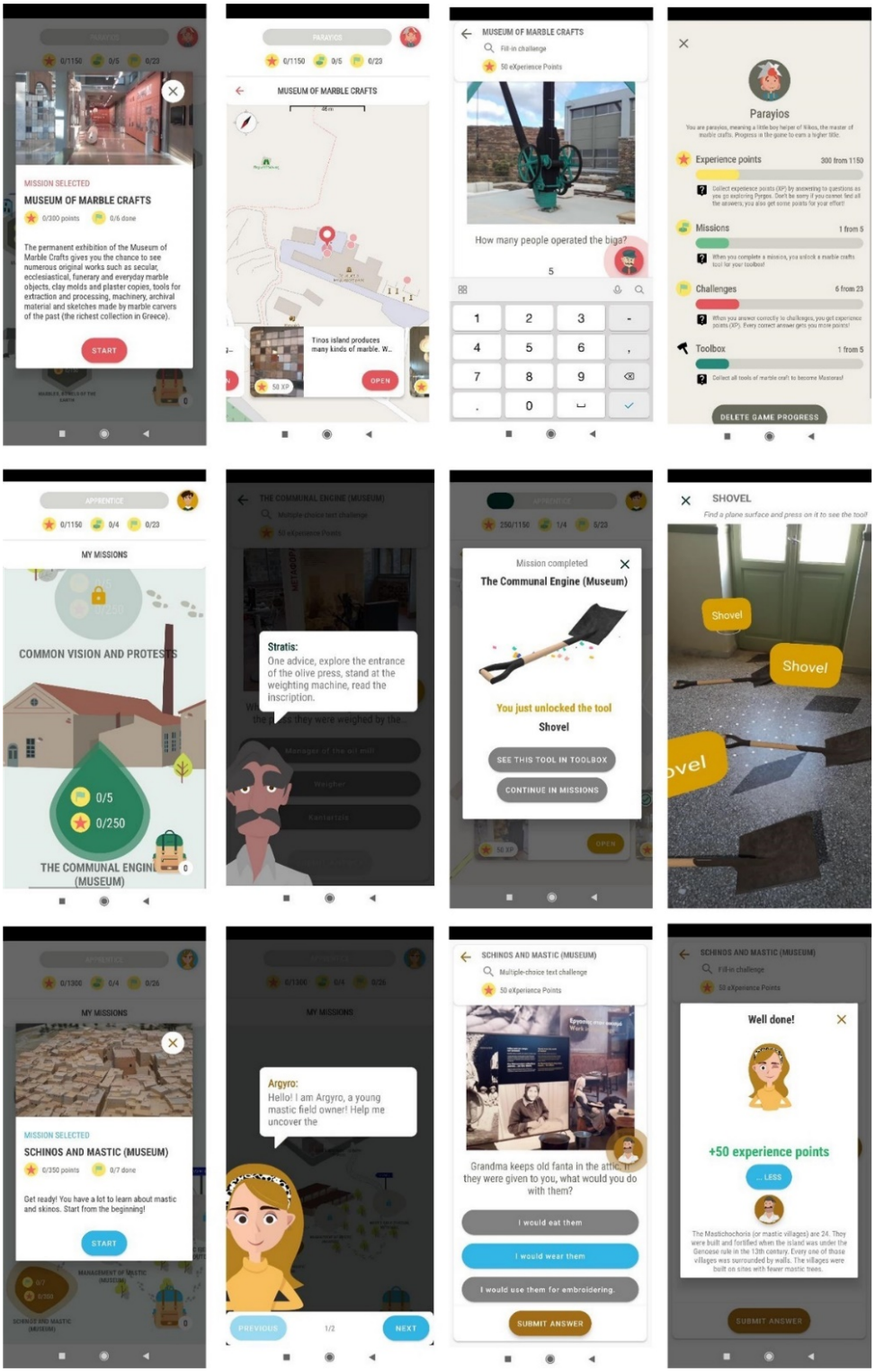

Figure 8. Screen shots of the final implementation of mobile games. Upper row: game 'Explore the Marble Town' (Mouseion Topos #Tinos). From left to right: a selected mission from mission map; the challenges map and list; a challenge question (fill-in type); the user profile screen. Middle row: 'People's Machine' game. From left to right: missions map; the master character helping on a challenge; a tool earned after mission completion; AR view of the tool. Lower row: 'Mastic and Mastichochora' game. From left to right: mission selected from the mission map; the young character onboarding; a challenge question (help is available in animation); challenge completion card with more information.

Figure 9. Posters in the museums and settlements that inform visitors about the mobile games.

In general, we observed that pupils were very enthusiastic with gameplay. They were very keen to explore the museums and find the correct answers to challenges. For example, several pupils were motivated to validate their correct answers (before submitting them to the game) using exhibit poster descriptions or the museum guide. Many pupils experienced the game competitively with peers, which was a fun experience for them, although this was not intended by our design. In addition, pupils like to play the game with one or two friends who share the same device. This is also the case with all other visitors, who visit the museum in small groups and play the game together on a single device.

At the end of the activity, we asked them to complete the UEQ (user experience questionnaire) [63], which is a fast and reliable questionnaire used to measure the user experience of interactive products. The responses to the UEQ are shown in Figure 10, and are very positive (higher than +0.8) for all aspects of the UX measured. According to [64], "it is extremely unlikely to observe values above +2 or below −2 . . . the standard interpretation of the scale means is that values between −0.8 and 0.8 represent a neutral evaluation of the corresponding scale, values >0.8 represent a positive evaluation and values <−0.8 represent a negative evaluation.

Since the release of the games (July 2021) we have also been monitoring **user analytics** (selected data are depicted in Table 6). Based on user analytics, we have made the following observations:

- Most visitors prefer to play the game; however, some just download the app and review the tour functionality of the app, possibly to identify more places to visit in the settlement. Most users use both tour and game functionality.
- The large majority of visitors are from Greece (according to their mobile network provider), which was anticipated due to the lower number of tourists from abroad in 2021 because of the pandemic.
- Engagement time ranges from 7 min to 19 min among the three islands. However, the actual engagement time should be much larger because the app is not always active during a visit (mobile phone screens timeout after a few seconds).
- Visitors play the game mostly in the museums and do not continue the game in the settlements. In Lesvos (People's Machine game), more than half of visitors finished the game (54%) because most of the challenges are in the museum and the surrounding space, while the settlement is very close to the museum. The other settlements are not that close to their museums.

- More than half of visitors select to view tools in AR in general. Notably, some older devices may not support AR functionality, so this is expected to increase in the future.

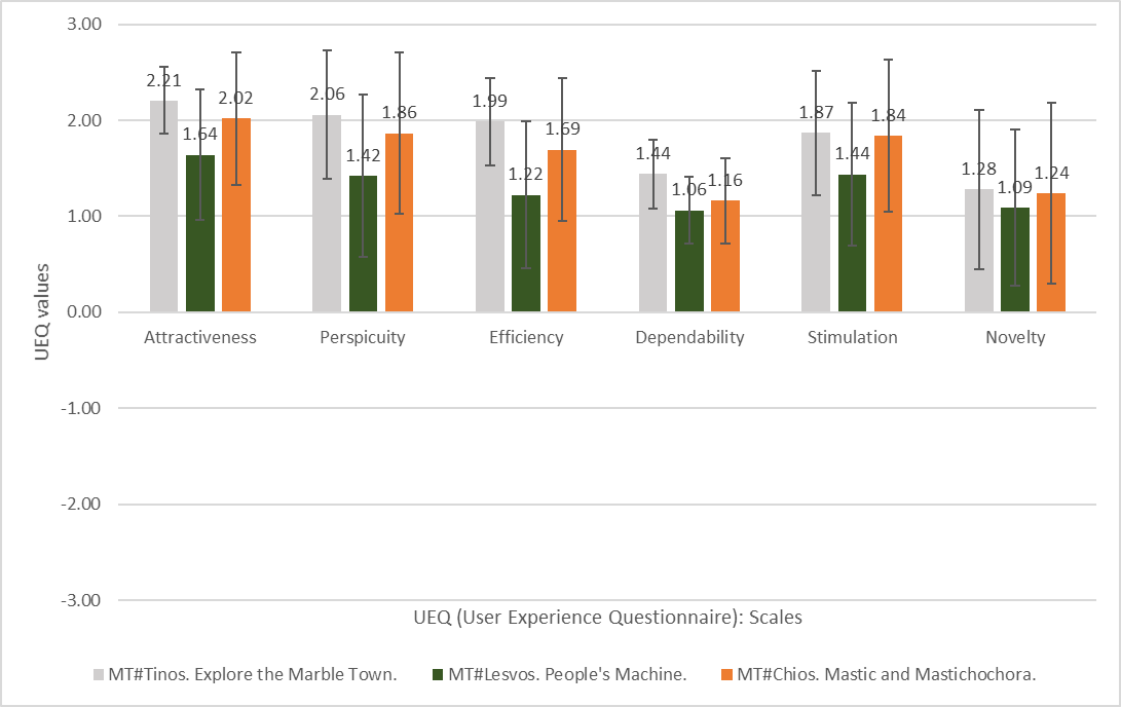

Figure 10. User Experience Questionnaire: responses from field study participants.

Table 6. Summary of data from user analytics (August–November 2021).

	Devices [1]	% Game	% Tour	% Greece	Engagement Time	Completed Game	Completed Challenges	Completed Missions	User Events Learn More	User Events Help	User Events AR View
Tinos	347	44%	67%	86%	7 m	14%	8 (from 23)	1.4 (from 5)	24%	34%	62%
Lesvos	151	87%	51%	91%	19 m26 s	54%	17 (from 23)	2.9 (from 4)	21%	33%	48%
Chios	107	72%	50%	92%	10 m2 s	22%	14 (from 26)	2.0 (from 4)	28%	20%	66%

[1] People visit museums in small groups (e.g., with friends or family) and often play the game on a single device.

In addition, during the past few months, after the mobile games were made available, we have often observed visitors and asked them the question of why they do *not* select to play the games. The most common answers to this question include:

- "I did not realize that there is a mobile game I can download and play" (did not see signs or they were not informed).
- "I do not have enough time for the visit."
- "I don't want to play. It may distract me from the visit."
- "Not ready to play" (for various reasons, e.g., families with infants or smaller children, people who carry luggage or bags from the beach, etc.).
- "The time of the day is not appropriate" (e.g., too hot).
- "I am an iPhone user."
- "My Android device does not support it" (either not a touch phone, or android OS less than version 7.0; notably the game can be installed and played in devices that do not support AR functionality; however, the user will not be able to view tools in AR).

Thus, there are several other reasons that may prevent them from playing the mobile games, such as visitor readiness, availability, as well as technical or weather conditions. These mobile games for cultural heritage require some of the visitors' time and effort; therefore, they could be further integrated into museum and visitor visits in many ways. Local museums and communities can help with information passing and sharing so that

mobile games are located and found promptly by visitors. In addition, the mobile games could be further integrated into museum activities, tours, and school visits.

5. Discussion

5.1. Representativeness, Centrality, and Availability of Participants in Co-Design Activities

Co-design activities are conducted in co-operation with various groups and participants. In order to enhance the relevance and importance of contribution, it is important to select participants that are representative of related groups that possess knowledge, skills, and experiences about cultural heritage. The question of who should be participating in co-design activities of cultural heritage has not been discussed deeply in the relevant literature, but we can draw a few conclusions from current practice.

In a project of LBGs for cultural heritage, participant groups may be numerous and include people with variable specialties, skills, and personal schedules. When the goal of co-design was the production of artifacts or tangible results, then our strategy of involvement was to include people in pairs (field playtesting, field studies) or small groups (in some sessions of field visits and field study). When the goal was to get feedback or review on several intermediate project outcomes (e.g., design brief, ideation), we tried to ensure the cross-disciplinary background of all people involved. In this case, and due to restrictions from the pandemic, we rested on synchronous and asynchronous communication to acquire feedback (e.g., video sharing of prototypes, walkthroughs in online prototyping tools, zoom meetings). Thus, several people in the community participated in the process and provided valuable input, including arts and crafts masters and workers, members of local administration (major, members of council), local scientific advisors of the museums, educators, pupils, etc.

5.2. Getting Tangible (Specific) Outputs from Participatory Design Processes

In cultural heritage technology projects, it is not common to use tangible artifacts or toolkits to co-design with participants to motivate their active participation and help them reveal tacit or latent knowledge. On the other hand, when participatory methods are used, such as co-design workshops, it is not always easy to reach tangible, specific results about the project progress. The design thinking mindset and process followed has helped participants to focus on results rather than on deliverables, timings, and other important but modifiable aspects of project development. However, what is tangible or specific output differs depending on each project phase and the goal of a co-design or participatory activity.

In a broad research activity, such as field visits, tangible output had many forms: stories, facts, knowledge, opinions, ideas, photographs, landmarks, videos, books, and others; therefore, it was important for us to store and share various resources obtained, as well as to create detailed minutes and notes to document the process and results. The ways we involved people in those visits were decided based on their own expertise and capacity. Field visits were essentially an exploratory method, and we also received tangible inputs in terms of local experts' own work that they shared with us, such as the fact that an educator, local heritage expert, and member of the community of Tinos (marble crafts) provided us with a mobile learning game he had developed several years ago with pen and paper. With other participants we followed other appropriate techniques based on their input and capacity, such as walkthroughs in the museums (local museum administrators) or the settlements (an architect in Chios, a civil engineer in Tinos, a former major in Lesvos); or representations of the work process (workers in Lesvos olive oil press, marble sculptors in the workshops, etc.).

In more focused activities, such as the field playtesting sessions where we were interested in specific actions that would reflect the UX, UI, and cultural content of the games, we provided participants with guidelines on how they would play the game (i.e., in pairs, they would talk aloud to discuss their questions, findings, etc.). Furthermore, we had constructed a documentation schema to classify findings quickly as we observed the participants. In any case, we did not intervene throughout the playtesting process to allow

players to move at their own pace and naturally interact with the games (except when we realized the need to co-create cultural content).

5.3. Transferable UX Design Insights from Field Playtesting

A unique aspect of our project was that the mobile games were a family of games for a museum network. This was a problem of both user experience and software engineering. From a UX perspective, we had to make design decisions early about the aspects that would be common among games, namely, high-level UX goals (sensitize visitors to local heritage, promote exploratory learning) and game elements (missions, challenges, experience points, player levels, rewards, tools). All cultural content, resources, and media were different, as were most of the graphics (including digital characters) to reflect local context. From a software engineering perspective, there was a need to start software development from several sub-projects that could be re-used in all three games, and to integrate them following a common system design (software architecture).

Field playtesting was also important for further distinguishing aspects of the game between the three locations. For example, in one game (Tinos), after playtesting it was decided to offer all missions unlocked from the start, in contrast to the other two games where the player must first complete the first mission to unlock the second, and so on. This was decided because it was not known if the user would start from the museum or from the settlement. For the other two games, we were advised and convinced that the large majority of players would first visit the museum, which is a landmark of the settlements and that most people visit first. These were to some extent investigated during the early phases of the project, but the decisions were finalized after field playtesting.

5.4. Co-Creation of Cultural Heritage Content via Field Playtesting

The possibility of co-creating cultural content between field playtesting sessions of mobile LBGs has not been discussed deeply in related work.

Content creation and curation were not initially trivial. For example, each challenge is stored in a table with 26 fields in the local database, including texts (x2 for Greek and English versions), numbers, recourse ids, etc. Additionally, content had to be historically sound and precise. There were multiple issues with terminology related to artisanal technology, processes, and tools. In addition, all terms had to be consistent with museum signs and guides. Thus, various errors appeared in cultural content production in the first version of the games that had to be identified by local and heritage experts.

Cultural heritage professionals had reviewed content twice before they played the game in field playtesting. During these reviews, they viewed content in documents or spreadsheets. However, when they played the game in the field it was far easier to make sense of the content and respond to other issues as well, e.g., about its appropriateness, and to propose better alternatives to particular challenges. Furthermore, it was easy to review content bound to the place and spaces, such as guidelines to navigate to the next challenge locations. Notably, even more ideas for content were produced but were not incorporated into the games because they would last even longer (they have been kept for possible future updates or enhancements).

One important prerequisite condition for productive playtesting in the field is the availability of fully functional games that have been tested in the lab beforehand. This ensures the emphasis on field testing is not distracted by possible bugs or trivial usability issues. When this is the case, it is possible for cultural professionals and experts to focus on content and provide various corrections, improvements, and further ideas on new content that is more appropriate or suitable.

5.5. How COVID-19 Affected Participatory Co-Design and Field Work

The restrictions imposed due to the pandemic affected project development in numerous ways.

The members of the research and design team were located in three different locations in Greece, and they could not meet in person for long periods of time during travel restrictions. The co-ordination of the design team was more difficult during these periods since that work had to progress asynchronously, or with extra flexibility to personal schedules. Of course, we made strong use of teleconferencing, online prototyping, and software development collaboration technologies.

The museums were closed for two extended periods of time due to lockdowns: a four-month period (March–June 2020) during the first wave of the pandemic and an eight-month period (November 2020–June 2021). The first lockdown period delayed the field playtesting for about three months, while the second lockdown caused a project delay to the release of the games of about six months. When museums were closed it was generally not possible to connect to the museum spaces even from distance, for example, to conduct a teleconference with museum staff inside the museum in order to confirm or complement data and content.

When museums were opened to the public this was according to COVID-19 protocols (including the use of face masks, limited number of visitors, etc.). All these limitations caused a considerable decrease in visitors in 2021 at about 40% compared to the year 2019 (the last year before the pandemic). Furthermore, school visits were very few since most schools visit museums in spring. The time duration of museum visits also dropped due to people taking precautions. These facts have certainly affected the adoption and engagement of visitors to mobile games as well.

6. Summary and Conclusions

This paper presented the participatory and co-design thinking process, methods, and outcomes for the development of LBGs for cultural heritage that promote intangible heritage about artisanal technology and arts and crafts acknowledged by UNESCO. Throughout the duration of the project, there was close co-operation with cultural heritage professionals and local communities in the three cultural sites. We emphasized the construction of fieldwork methods: field visits at the start of the project, field playtesting to inform the detailed design and software prototypes, and field studies at the release of the mobile games for fine-tuning and further user experience issues.

Previous work in the co-design and participatory design literature has focused on particular co-creation methods that may be applied in short-term, focused activities, while the work in this paper presents a long-term articulation of methods with a detailed account of results and reflections. The work presents the following contributions to contemporary participatory and co-design for LBGs for cultural heritage:

- It presents a detailed case study of applying the design thinking process to LBGs for cultural heritage, with emphasis on long-term involvement of professionals, local experts, and visitors (players, users) in various phases (empathize, define, ideate, prototype, test, and implement). Previous work on the co-design of mobile games for cultural heritage emphasizes the co-creation phase with particular methods such as workshops and board games.
- It presents the design of transferable user experience (UX) of mobile games for a network of museums. We illustrate how these games can have common high-level UX goals, game elements, and system design, but different cultural content, resources, and media and graphics. This is distinct from previous work which emphasizes co-design of a single LBG.
- It introduces the methods of field visits, which is a composite, fast-paced method to gain empathy for and sensitization to the people, the context and heritage.
- It further documents the method of field playtesting with the constructive interaction of experts (originally introduced in [4]) with respect to outcomes related to co-creation and curation of cultural content in the field.

We envisage that this work can provide a useful account of applying participatory design and the design thinking process in mobile games for cultural heritage to other designers and practitioners.

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