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Shine Bright Like Silver: A Mobile Museum Companion for Gamified Learning and 3D Simulation on Traditional Silversmithing

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Abstract

This paper presents the design, implementation, and evaluation of Shine Bright Like Silver, a mobile application developed for PIOP's Silversmithing Museum in Ioannina, Greece, to document, simulate, and present the sand casting and filigree silversmithing techniques. The proposed solution integrates semantic knowledge graphs, an interactive crafting simulation, and gamified learning elements to externalize and operationalize the implicit procedural knowledge involved in the craft. A user study was conducted with n=26 museum visitors to assess the system's effectiveness in terms of usability, learning outcomes, and early indicators of craft valorization. The findings suggest that combining semantic representation with interactive simulation, embedded within a museum context, offers a scalable and replicable framework for the digital preservation of heritage crafts. The work contributes to the broader discourse on technology-mediated craft education by illustrating how tacit knowledge can be systematically captured and transmitted through mobile digital environments, and by positioning visitor-facing tools within a broader reenactable preservation infrastructure.

Keywords: tacit knowledge; silversmithing; semantic knowledge graphs; interactive simulation; gamification; museum digital experience; intangible cultural heritage; craft education

1. Introduction

1.1. Traditional Silversmithing and the Erosion of Tacit Knowledge

Silversmithing in Ioannina, Greece, exemplifies a craft whose mastery has been accumulated over generations through apprenticeship and hands-on practice. Like many traditional domains, it now faces a convergence of pressures: an ageing practitioner base, changing market conditions, and competition from industrial production. The risk is that such practices persist primarily as curated museum exhibits rather than as living, transmitted skills. Conventional safeguarding strategies, such as cataloguing objects, documenting tools, and recording procedures, capture the visible and codifiable aspects of the craft but leave the expert's perceptual acuity and motor coordination unrecorded. In crafts where subtle variations in force, timing, and responsiveness to material determine quality and cultural identity, this unspoken, embodied layer of knowledge is precisely what is most at risk of disappearing.

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1.2. Valorisation, Object Biographies, and Circular Models

European policy has increasingly positioned knowledge valorization as a mechanism for converting research and cultural assets into societal, economic, and cultural value. In the context of crafts, valorization extends beyond commercial outcomes to include enhancing public visibility, sustaining cultural relevance, and aligning practice with circular and sustainable models of production and consumption. The concepts of object biographies and product–service systems reframe artefacts as entities that move through phases of design, fabrication, circulation, use, maintenance, and eventual transformation or reuse. Circular product biographies build on this by foregrounding loops of repair, repurposing, and recycling, situating craft products within wider environmental and economic debates. Digital tools communicate these biographies while enabling learning and engagement, and are a compelling avenue for strengthening the cultural standing and market viability of traditional crafts.

1.3. The Craeft Project and the Valorisation Pilot

Craeft, a Horizon Europe-funded initiative, treats craft-making as an integrated interplay among perception, cognition, and embodied action, and seeks to model this integration computationally to improve the documentation and transmission of high-dexterity crafts. Within Craeft, the Valorization Pilot explores how digital experiences, game-based interventions, retail-support tools, and maker-centered activities can enhance the perceived value and long-term sustainability of craft practices. Silversmithing in Ioannina (RCI6) serves as a principal testbed, combining the challenge of reenactably preserving tacit knowledge with the practical need for public engagement and market-facing support. The Shine Bright Like Silver application was developed in this context as a mobile companion to the PIOP Silversmithing Museum of Ioannina, designed to bridge the museum's historical collection with the living heritage of making and the contemporary practitioners at the Ioannina Traditional Crafts Centre (KE.PA.VI.).

1.4. Research Problem and Objectives

Heritage scholarship is gradually moving away from a reliance on static 2D and 3D documentation toward approaches that weave together anthropological understanding, cognitive perspectives, and haptic technologies to represent how crafts are actually performed. Concurrently, research on mobile museum guides and gamified heritage applications has shown that digital tools can enhance visitor engagement and learning outcomes, yet frequently operate independently of deeper models of tacit knowledge and of the economic realities facing craft communities. Few existing examples tightly couple public-facing digital tools with frameworks that address maker–material negotiation, embodied feedback, and explicit valorization goals in high-dexterity craft domains. This paper addresses this gap through the design and empirical evaluation of a mobile application that is simultaneously an informal learning companion within the museum setting, a connector between heritage and living practitioners, and an accessible entry point into a broader reenactable preservation infrastructure.

Accordingly, the overarching objective of this work is to examine how a co-designed mobile companion can foster visitor learning, engagement, and early indicators of valorization in the context of Ioannina silversmithing. Specifically, the paper aims to: (i) describe the design rationale and implementation of Shine Bright Like Silver, (ii) evaluate its user experience, perceived learning impact, and influence on visitor attitudes and intentions, and (iii) situate the application within Craeft's broader program on reenactable preservation and craft-support infrastructures.

1.5. Contributions and Paper Structure

This paper makes three principal contributions at the intersection of heritage studies and human–computer interaction.

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First, it introduces `Shine Bright Like Silver', a bilingual, offline-capable mobile application that integrates a guided museum tour, craft-specific mini-games, an introductory sand-casting simulation, and feedback mechanisms customized to the silversmithing collection of the Ioannina museum.

Second, it presents a mixed-method evaluation with museum visitors, combining the User Experience Questionnaire (UEQ) with custom items measuring learning, experience economy, and legacy perceptions, supplemented by qualitative feedback on content, usability, and perceived value.

Third, it positions the application within Craeft's reenactable preservation framework, examining how visitor-facing tools can interface with haptic intelligence, semantic knowledge representation, and valorization strategies to support the sustainability of high-dexterity crafts.

The paper is organized as follows. Section 2 reviews related work on digital cultural heritage experiences, gamification in learning contexts, reenactable preservation approaches, and haptic knowledge representation, identifying the specific research gap addressed. Section 3 describes the Ioannina silversmithing context, outlines the design goals, details the Shine Bright Like Silver system architecture and implementation, and explains the evaluation methodology. Section 4 reports the empirical findings on user experience, learning outcomes, and valorization-related measures, alongside qualitative insights from visitor feedback. Section 5 discusses the implications for heritage valorization and HCI design, connects the results to reenactable preservation agendas, and outlines limitations and directions for future research. Section 6 concludes the paper.

2. Background and Related Work

This section reviews prior work that informs the design and evaluation of Shine Bright Like Silver, focusing on digital cultural heritage experiences and mobile guides, gamification and games for cultural mediation and learning, reenactable preservation and tacit knowledge capture, and haptic intelligence and knowledge representation in heritage.

2.1. Digital Cultural-Heritage Experiences and Mobile Guides

The digital transformation of cultural heritage has generated diverse visitor-facing technologies such as mobile guides, augmented reality (AR) applications, interactive installations, and digital storytelling platforms, etc. that shift the visitor role from passive observer to active participant.

Mobile guides and location-aware applications are among the most widely adopted forms of digital mediation in museums. Tomiuc [1] examined how mobile technologies enhance museum visits through contextual information, wayfinding, and personalized content. Damala [2] demonstrated that handheld devices can alter or enhance the visiting experience by offering alternative interpretive layers. More recently, Cardoso et al. [3] showed that mobile applications tailored to visitor preferences significantly affect satisfaction and perceived value.

AR has emerged as a powerful modality for overlaying digital content onto physical heritage contexts. Koo et al. [4] reported that visitors found AR-enhanced navigation and information access intuitive and engaging. Boboc et al. [5] highlighted the trend toward markerless, smartphone-based AR that integrates naturally into visitor behavior. Hammad et al. [6] found that markerless AR made museum visits more interactive and informative, while Othman et al. [7] confirmed that mobile AR/VR systems have transformed how visitors explore historical sites. Marto and Goncalves [8] concluded that mobile AR can effectively support on-site heritage interpretation when designed with visitor context in mind.

Digital storytelling organises heritage content narratively rather than encyclopedically. Psomadaki et al. [9] showed how narrative strategies promote active engagement in cultural heritage (CH) management. Sun and Dong [10] demonstrated that digital storytelling fosters visitors' sense of place and identity across all phases of the experience. Lalopoulos et al. [11] found that a mobile application enhanced intangible CH through storytelling, improving visitor engagement. Economou and Young [12] evaluated the EMOTIVE experiences at the Hunterian Antonine Wall, finding that digital narratives can enhance visitor connections with objects while maintaining scholarly rigour.

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Vrettakis et al. [13] noted the potential and the spatial constraints that heritage sites impose on mobile storytelling. Kysilick et al. [14] demonstrated how object biography approaches are digitally rendered to highlight the artefact's significance.

Gamification in mobile heritage applications has also attracted significant attention. Paliokas et al. [15] showed that combining game mechanics with AR increases visitor motivation and knowledge acquisition. Khan et al. [16] identified gaming methods that provide heritage learning scenarios based on historical themes. Marques et al. [17] called for more studies on gamification as a vehicle for deeper cultural engagement. Nofal et al. [18] found that tangible interactive paradigms significantly improve engagement and collaboration among young visitors. Tongpaeng et al. [19] demonstrated that gamification influences learning stages and enhances engagement in MR museum contexts. Galindo-Durán [20] showed improvements in motivation and learning outcomes through gamification for artistic heritage education.

Evaluation of mobile heritage applications has increasingly adopted mixed-method approaches. Chatsiopoulou and Michailidis [21] highlighted that successful applications combine trivia, puzzles, mini-games, and reward mechanisms. Srdanović et al. [22] demonstrated how mobile applications can explore gamification strategies for cultural artefacts through 3D interaction. Philippopoulos et al. [23] proposed a holistic mobile application for personalized presentation, entertainment, and learning, evaluated by user-centred methods. Tesoriero et al. [24] found that mobile devices serve as an effective alternative to traditional audio guides when integrated thoughtfully into exhibition spaces.

Collectively, these studies establish that mobile, AR-enhanced, and gamified applications can meaningfully support learning, engagement, and personalization in museum settings. However, several limitations persist. First, most applications remain content-delivery oriented, presenting pre-authored information rather than connecting visitors to living craft practices or tacit knowledge. Second, many systems focus on tourist-oriented heritage sites rather than smaller, craft-specific museums where the connection between historical collection and contemporary practice is central. Third, while gamification and AR have been evaluated for engagement and usability, fewer studies examine their role in supporting knowledge valorization, which is the transformation of heritage knowledge into tangible cultural, social, and economic value for craft communities.

2.2. Gamification and Games for Cultural Mediation and Learning

A substantial body of work investigates gamification in CH [25–32]. Gamification, understood as embedding game mechanics and motivational structures into non-game contexts, has been used to foster exploration, repetition, and mastery. Kang et al. apply gamified learning to bamboo papermaking, demonstrating that progressive difficulty and feedback loops can replicate aspects of craft apprenticeships and support dissemination in intangible cultural heritage (ICH). Varli et al. extend this perspective to architectural and CH education, showing that game-based strategies can move learners beyond passive reception toward more embodied, decision-driven engagement [32]. Phongsophol et al. focus on virtual museum visits and find that quests, achievements, and rewards can improve visitor engagement, particularly among tourists, by structuring attention so that educational content is not overlooked [30].

These studies suggest that gamified experiences are accessible gateways to heritage knowledge, provided that the mechanics are aligned with narrative integrity and learning goals. Most examples, however, remain purely digital, whereas many traditional crafts are inherently tactile and materially grounded. This creates a gap for systems that combine game-based structures with on-site, material encounters. Shine Bright Like Silver responds to this gap by embedding mini-games and interactive quiz videos into a mobile application designed for use in a museum, where visitors can simultaneously observe physical tools, materials, and demonstrations.

Related work on board and analogue games as learning media highlights the educational value of physical components and co-located interaction. Mendes and Correia report that board, tabletop, and analogue game-based approaches are particularly effective for supporting collaboration and

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situated practice [29]. Bayeck argues that board games do not compete with digital games but offer distinctive affordances: shared space and tangible pieces create "interaction laboratories" where players externalize strategies, negotiate rules, and collectively reflect on consequences. Lin et al. demonstrate that technology-enhanced board games can improve academic achievement, motivation, and engagement in primary mathematics education [25]. These findings suggest that learning gains arise from explicit content and from affective qualities such as enjoyment, competition, and collaboration.

A smaller, directly relevant strand explores games for traditional crafts and intangible heritage. Again, Kang et al. provide a touchstone through their bamboo papermaking case [27], while Sulaiman and Samsudin show how traditional children's games embody socio-cultural knowledge and support intergenerational continuity [31]. Camuñas-García et al. examine heritage-based video games more broadly and argue that such games can effectively model artisanal practices if they retain narrative and contextual authenticity [26]. These insights underpin Shine Bright Like Silver's use of focused mini-games and interactive videos to communicate silversmithing processes, while anchoring them in documented practice and real museum exhibits.

2.3. Reenactable Preservation and Tacit Knowledge Capture

Recent heritage research has argued for a fundamental shift from static documentation toward reenactable preservation, particularly for high-dexterity crafts. Traditional 2D and 3D digitization methods, such as photography, scanning, and static metadata, are essential but insufficient for safeguarding skills that rely on tacit knowledge, fine motor control, and dynamic interaction with materials. Yang [33] highlighted that specialized skills, pattern recognition, and gesture-based knowledge embedded in digitization processes resist straightforward codification. Gelvez et al. [34] proposed a framework for tacit knowledge in craft-based manufacturing, categorizing skills into motor operations, tool handling, and movement recording, arguing that all tacit knowledge of an artisanal process can be digitized with appropriate digital interventions.

Conventional ethnographic observation and narrative description, although valuable, lack the capacity to capture the internal feedback loops and sensorimotor adjustments that characterize expert performance. Zabulis et al. [35] conducted a digitally enhanced ethnography for understanding craft actions and processes, modelling the full depth of embodied knowledge and material interactions. Flanagan and Fraietta [36] explored how haptic contact between fingers and materials can be linked to ethnographic and manufacturing sound data. Dubé [37] argued that craft knowledge is accumulated through generations via direct haptic and embodied modes of transmission, drawing on ethnographic surveys of folk craft traditions.

Heritage science is therefore moving toward multidisciplinary approaches that combine anthropology, cognitive science, and haptic and motion-capture technologies to model how actions unfold. Zhang [38] showed that advances in markerless motion capture driven by convolutional architectures can form the foundation for intelligent digitization of tacit knowledge. Kajazi [39] developed an AR-supported knowledge transfer system using motion tracking and process visualization, distinguishing between motor skills, tool handling, and procedural knowledge types. Prabhuv [40] proposed a framework for digitizing manual manufacturing task knowledge, using gaming interface technology and standard human skeletal motion tracking.

The concept of the Maker–Material–Negotiation has emerged as a useful analytical lens for understanding this embodied dialogue. Aktas and Mäkelä [41] found that the interaction between maker and material in craft making is embedded in practice, often in tacit forms, and is perceived as a collaborative action. Hawkins and Price [42] brought to light the affective force of maker–material relations and the embodied accumulation of skill through auto-ethnographic representations. Desmarais [43] examined how actors know tacitly how to "go on" in craft situations, combining skilled manual practice with inclusive ethnographic approaches.

In the domain of knowledge representation, existing ontologies for CH provide robust but object-centric structures that do not natively support dynamic, sensorimotor events. Stoyanova et al.

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[44] noted that CIDOC-CRM remains the main ontology but is oriented toward CH objects and events rather than fine-grained action sequences. Doerr et al. [45] described the Europeana Data Model (EDM) as flexible yet similarly oriented toward artefacts and provenance rather than embodied practice. Cui et al. [46 proposed an ontology-based approach extending CIDOC-CRM with subclasses for process-oriented modelling, but without the granularity needed for high-dexterity craft actions.

To address this gap, recent work has begun extending heritage ontologies toward action and affordance modelling. Partarakis et al. [47] externalized tacit craft knowledge through semantic graphs and real-time VR simulation, extending the CIDOC-CRM model to accept keyboard, mouse, and haptic student inputs. Makris et al. [48] developed a knowledge graph-driven interactive 3D simulation for craft training, selecting CIDOC-CRM as the ontological foundation and planning integration of haptic feedback and motion capture. Doulgeraki et al. [49] extended CRM classes with subclasses for knowledge representation, creating an inventory of ICH through semantic encoding.

Parallel efforts in haptic feedback and simulation have explored how sensorimotor fidelity can support craft skill learning. Jose et al. [50] developed haptics-enhanced multi-tool virtual interfaces for training carpentry skills, using computational models to render haptic feedback and track skill learning curves. Väpenstad et al. [51] found that training on simulators with unrealistic haptic feedback can negatively affect training outcomes, underscoring the importance of haptic fidelity. Patel [52] proposed a taxonomy of haptic devices and a tactile interface for VR-based manufacturing training, enhancing skill acquisition in manufacturing contexts.

2.4. Haptic Intelligence and Knowledge Representation in Heritage

A technical challenge for reenactable preservation is linking haptic intelligence conceived as the felt sense of material resistance, tool feedback, and bodily effort to formal knowledge representation (KR) systems that are interoperable with existing cultural heritage standards. Hui and Nasir [53] argued that haptic intelligence, aesthetic judgment, and embodied material knowledge cannot be fully encoded through conventional digital tools without undermining the preservation of ICH. The Crafts-led Innovation project [54] positioned haptic intelligence as a distinguishing feature of living CH, proposing that craft-specific simulators and immersive technologies can embed it into digital systems. McGhugh [55] argued that haptic intelligence is a fundamental dimension of artistic practice, emerging from the analysis of learning and construction processes. Huang [56] proposed that architecture should possess “haptic intelligence” through design, rather than crafting a single optimal object.

Existing heritage ontologies provide robust but object-centric structures that do not natively support dynamic, sensorimotor events at the granularity required for high-dexterity crafts. Kelly [57] argued that knowledge representation in heritage mostly bears affordances that computing can partially address but not resolve. Zabulis et al. [35] combined embodied knowledge modelling with semantic knowledge representation to document affordances in craft knowledge, developing an ontology where elements such as tools provide the affordance of craft actions. Zabulis et al. [58] built multimodal dictionaries for traditional craft education on top of semantic knowledge representation, extending the Crafts Ontology (CrO) to support heritage preservation and AI systems in craft contexts. Wei [59] mapped structured data onto the Semantic Web using knowledge representation model ontologies to publish open data of heritage vessels.

The CrO has emerged as one of the most developed efforts to represent craft knowledge semantically. Zabulis et al. [60] proposed a representation protocol for traditional crafts, building a semantic craft ontology to present crafting processes and preserve embodied skills. Zabulis et al. [61] used the CrO for describing CH content linked to a craft, employing Semantic Web technology to support digital preservation. Partarakis et al. [62] argued that accurate documentation of craft knowledge requires an ontology that includes contextual and semantic knowledge, with ontologies serving as a key ICT perspective for describing craft processes. Isa et al. [63] took an ontological approach for creating a brassware craft knowledge base as a medium of digital preservation. Partarakis et al. [64] developed a web-based platform for traditional craft documentation, building

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on the CrO supporting semantic interoperability. Molee et al. [65] proposed an ontology-based digital preservation framework for Phum Riang silk heritage in accordance with Semantic Web standards. Liang et al. [66] presented an ontology-based construction of an embroidery intangible CH knowledge graph using semantic web technologies.

To address the gap between existing heritage ontologies and the needs of craft reenactment, recent work has extended knowledge representation toward action and affordance modelling. Zabulis et al. [67] recommended creating an ontology that can represent craft knowledge at multiple levels. Partarakis et al. [62] developed an approach for modelling action and affordance, representing semantically the physical entities and actions that take place during craft fabrication. Makris et al. [48] developed a knowledge graph-driven interactive 3D simulation for craft training, selecting CIDOC CRM as the ontological foundation and integrating relations used in their knowledge representation model.

Parallel efforts in haptic simulation and VR training have explored how sensorimotor fidelity supports skill acquisition. Ye [69] validated a VR training simulator providing trainees with motor-skill learning pipelines using three haptic feedback methods: passive, active, and combined. Patel [52] argued that haptic feedback has the potential to revolutionize skill learning in virtual reality through enhanced training simulators. Lopez et al. [70] found that VR and haptic feedback are gaining traction for targeted training experiences, though extension to craft professionals remains limited. Jose et al. [50] designed haptics-enhanced multi-tool virtual interfaces for training carpentry skills, using computational models to render haptic feedback and track skill learning curves. Ipsita [71 proposed an approach for psychomotor skill learning with multiple pathways to digitize expert motor skills and guide novice trainees through proprioceptive and haptic feedback. Ji et al. [72] combined generative AI with haptic and visual feedback to support skill acquisition in an immersive wheel-throwing environment.

Shine Bright Like Silver is situated at the edge of this technical stack. While the app does not implement haptic feedback or advanced simulation, it draws on the same conceptual vocabulary and broader architecture of techniques and process steps. This alignment is important for future integration: narratives and interactions introduced in the museum app can be linked, conceptually and technically, to richer reenactable representations and haptic training tools developed elsewhere in Craeft.

2.5. Summary of Research Gap

The literature reviewed in Sections 2.1 through 2.4 reveals a clear pattern of convergence and persistent gaps. In the domain of digital cultural heritage experiences, mobile guides, AR-enhanced applications, and digital storytelling platforms have demonstrated their capacity to support personalization, engagement, and learning in museum settings [1–24]. However, most systems remain content-delivery oriented, presenting pre-authored information rather than connecting visitors to living craft practices, tacit knowledge, or valorization pathways. Evaluations tend to focus on usability, engagement, and learning outcomes, with fewer studies examining the role of such applications in supporting broader valorization objectives for craft communities.

In the domain of gamification and games, gamified approaches have been shown to improve visitor engagement, motivation, and learning in heritage contexts. Board-based and tangible games have demonstrated value for collaborative, situated learning [25–32]. Most implementations, however, remain purely digital or disconnected from the material, high-dexterity character of traditional crafts. There is a scarcity of systems that combine game-based structures with on-site, materially situated encounters and with deeper models of craft process and tacit knowledge.

In the domain of reenactable preservation and tacit knowledge capture, the shift from static documentation toward embodied, haptically informed, and motion-capture-based approaches is well documented [33–53]. The Maker–Material–Negotiation has been established as a useful analytical lens for understanding embodied craft dialogue [60–62], and semantic ontologies such as the CrO

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have been developed to represent craft knowledge at multiple levels [63–70, Section 2.4]. Yet these infrastructures are rarely coupled to public-facing tools in operational museum settings.

In the domain of haptic intelligence and knowledge representation, the gap between object-centric heritage ontologies (CIDOC-CRM, EDM) and the needs of dynamic, sensorimotor event representation is acknowledged [45,63–65], and haptic simulation work in craft-adjacent domains shows promise for supporting skill acquisition [69–72]. However, existing heritage ontologies do not natively exhibit the granularity required for high-dexterity craft actions, and haptic simulation research is largely focused on manufacturing and construction rather than traditional craft training.

Consequently, there is a lack of integrated case studies where:

- a public, museum-based mobile application is explicitly informed by reenactable preservation and haptic-KR frameworks;
- gamified and interactive elements are grounded in documented, materially situated craft practice;
- evaluation is conducted that addresses not only user experience and learning but also early signals of valorization and connection to living craft communities; and
- the developed application is positioned within a broader impact-oriented agenda that draws on established heritage evaluation frameworks.

Shine Bright Like Silver addresses this gap by combining a mobile museum companion with craft-specific mini-games and interactive videos, situating it within Craeft's reenactable preservation and semantic-authoring agenda, and empirically examining its impact on visitors' experience, learning, and perceptions of traditional silversmithing in Ioannina.

3. Materials and Methods

3.1. Case Study Context: Ioannina Silversmithing and KE.PA.VI

The Shine Bright Like Silver application was developed as part of the valorization pilot within the Craeft project, which deploys digital tools across eight Representative Craft Instances (RCIs) encompassing diverse materials, techniques, and cultural contexts. Within this broader framework, the Ioannina silversmithing pilot focuses on a craft tradition with deep historical roots in the Epirus region, extending from the post-Byzantine period into the present day. The pilot is structured around four dimensions: experiences, games, retail, and makers, each representing distinct pathways through which digital tools can support craft valorization.

The experiences dimension encompasses activities related to silversmithing alongside other crafts such as wood carving, glassblowing, and pottery, reflecting Craeft's multi-craft approach. The retail dimension engages with tangible craft products drawn from glass, silver, and textiles, connecting digital interventions to material artefacts and market-facing contexts. The games and makers' dimensions articulate broader aspects of craft practice, particularly the embodied knowledge and procedural understanding involved in craft making. For the silversmithing use case, this structure is instantiated through a set of mini-games, including Step by Step, Right Tool Right Process, Memory Game, and How It's Made, designed to convey the procedural and material logic of traditional techniques to museum visitors.

The pilot engages two complementary physical sites that together constitute the silversmithing ecosystem in Ioannina. The first is the Silversmithing Museum, operated by the Piraeus Cultural Foundation (PIOP) and housed within the Castle of Ioannina. The museum's permanent exhibition presents the technology of silversmithing during the pre-industrial period, covering traditional techniques of shaping and decorating silver objects through textual, visual, and multimedia materials. Its collection includes Epirote silver and goldsmithing works from the 18th through the 20th century, encompassing utilitarian objects and ceremonial pieces. The museum serves as the primary deployment site for Shine Bright Like Silver, where visitors interact with the application in proximity to the physical artefacts and exhibition spaces that form the referential basis of the digital content.

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The second site is KE.PA.VI. (Centre for Vocational Training of Ioannina), which functions as the living-practice counterpart to the museum's historical presentation. KE.PA.VI. hosts active silversmithing workshops and training programs, maintaining a connection to the craft as a continuing practice rather than solely as heritage. This dual-site configuration allows the pilot to address the archival and the living dimensions of the craft, situating the application within a continuum from historical documentation to contemporary practice and skill transmission.

The application provides users the option to navigate through three main museum stations. The top navigation bar provides access to the side menu and a return arrow, supporting non-linear exploration. A progress indicator system tracks game completion across the mini-games: green checkmarks appear next to games the user has already completed, while games without a checkmark remain visually distinct, guiding the user toward remaining content. This design choice reflects a deliberate balance between guided progression and user autonomy, allowing visitors to construct their own path through the experience while maintaining a sense of overall structure and accomplishment.

The application was deployed on-site at the Silversmithing Museum during a defined evaluation period, during which museum visitors were invited to interact with the application as part of their visit. The evaluation design and outcomes are described in detail in Section 3.6 and Section 4, where we report on user experience, learning, engagement, and valorization-related outcomes based on a sample of n=26 visitors.

3.2. Design Goals and User Requirements

The design of Shine Bright Like Silver was guided by requirements elicitation conducted through a co-design workshop informed by Europeana's Impact Playbook [73]. The workshop had two objectives: to identify the relevant stakeholders for an introductory craft experience and to define the desired short- and long-term outcomes of the activity. The process proceeded through stakeholder prioritization, empathy mapping, and value-lens analysis, ultimately producing a set of design goals that shaped the application's content and interaction design.

Stakeholder identification began with a brainstorming exercise to surface all parties with a potential interest in an introductory crafting experience at the museum. These candidates were then positioned on a two-axis prioritization matrix: one axis indicated the stakeholder's importance to the project, and the other indicated how directly or indirectly the stakeholder would be affected by the activities. Museum and art curators were identified as important but indirectly affected by the museum's activities. Educators and the general audience were assessed as neutral on both dimensions. The group that emerged as most relevant was makers, artists who incorporate craft techniques into their practice, and craft enthusiasts. Within this group, a further distinction was made between professional makers, for whom craft is a source of livelihood, and casual makers, who engage with craft as a hobby. Given the museum context and the introductory nature of the experience, the design team selected craft enthusiasts as the primary target stakeholder group.

An empathy map was developed to build a richer understanding of the craft enthusiast's profile, needs, and expectations. Several observations informed the design. Craft enthusiasts reported limited exposure to rich digital experiences related to crafts in museum settings, indicating a gap that the application could address. Their motivation for visiting PIOP museums stems from a genuine enthusiasm for craft and industrial heritage, suggesting that the content should honor traditional depth and authenticity. While activities and comprehension levels vary with visitors' prior knowledge, the group demonstrated a willingness to deepen their understanding and an openness to new formats of engagement. This profile positioned craft enthusiasts as a suitable audience for experiential learning and for providing meaningful feedback on the application.

The value-lens exercise defined the desired outcomes across short- and long-term horizons. In the short term, the goal was to stimulate curiosity, i.e., to "nudge" visitors toward further interest in the craft following their museum experience. The application was expected to provide information beyond what is available in the existing exhibition, enriching the visitor's understanding of

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techniques, materials, and the cultural logic of silversmithing. The long-term aspiration was for visitors to feel more connected not only to the local craft community but also to the broader European community of practitioners and enthusiasts. By providing more enriching cultural experiences, the application was positioned to contribute to informal knowledge transmission and to the safeguarding of the craft as a living tradition. The team acknowledged, however, that accountability could reasonably extend only to short-term outcomes directly tied to the experience itself, such as engagement, self-reported learning, and behavioral intentions following the visit.

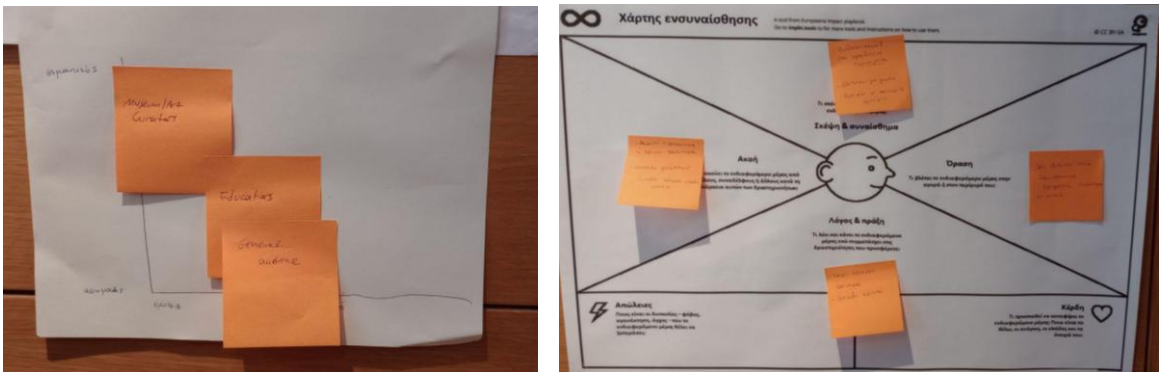

Figure 1. PIOP's Stakeholder Prioritisation and Empathy Map.

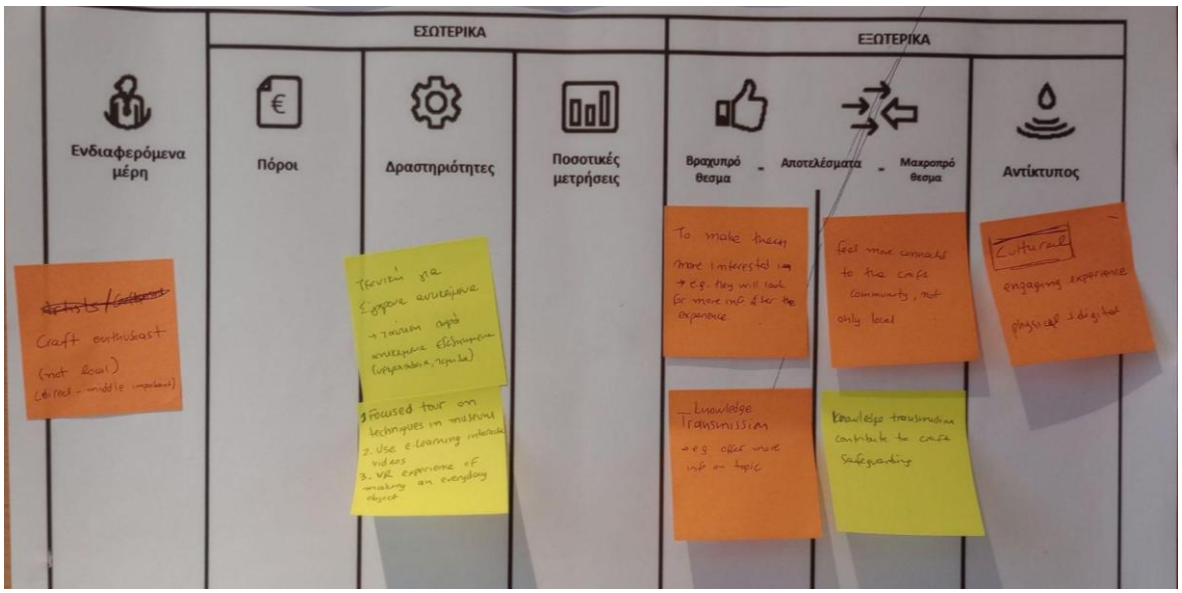

Figure 2. PIOP's Change Pathway.

The design process was further informed by the project's broader work on understanding and transmitting knowledge about specific craft gestures across Representative Craft Instances. The team defined the scope of the introductory experience around the techniques of the RCIs involved in Craeft, with particular focus on silversmithing for the Ioannina pilot. The guiding idea was to develop a targeted museum experience that connects traditional techniques with contemporary, everyday objects, helping visitors recognize the timelessness and continuity of craft practices across historical periods.

The preliminary scenario envisioned a multi-modal experience comprising a focused museum tour on techniques, interactive learning materials delivered via Craeft's e-learning platform, and a virtual reality (VR) experience of crafting an everyday object. The scenario assumed that interested visitors could reserve the experience in advance of their museum visit. However, practical constraints led to a revision of this plan: the museum does not have sufficient on-site staff to support a guided physical experience or to manage the distribution of digital devices to visitors. This constraint shaped

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the final design decision to develop a standalone mobile application that visitors could download and use independently, without requiring staff intervention or device provisioning. This requirement for self-guided, device-agnostic use became a central feature in the interaction design and technical architecture of the final system.

3.3. System Overview: Shine Bright Like Silver

Shine Bright Like Silver is a mobile application developed for Android smartphones and tablets, designed to function as a self-guided digital companion for visitors to the Silversmithing Museum of Ioannina. The application was produced within the valorization pilot of the Craeft project, as part of the Ioannina silversmithing Representative Craft Instance (RCI). Its primary purpose is to enrich the museum visit by providing interactive, technique-focused content that complements the physical exhibition, stimulates curiosity about the craft, and supports informal knowledge transmission.

The application positions itself at the intersection of three functional roles: a museum guide, an interactive learning tool, and a bridge between the museum's historical presentation and the living craft practice represented by KE.PA.VI. (the Traditional Craft Centre of Ioannina). It was developed to address the design goals identified in Section 3.2, namely, to "nudge" visitors toward deeper engagement with silversmithing, to offer information beyond the existing exhibition, and to foster connections to the local and broader craft community. The system is structured around five sections, accessible from a carousel-based main menu:

- Techniques Museum Tour: A guided exploration of three exhibition stations: Sand Casting, Filigree, and the Traditional Craft Centre of Ioannina, combining physical exhibition engagement with digital interactive content. Each station includes instructional text, audio narration, video material, and mini-games that test understanding of the techniques.
- Interactive Learning Material: A technique-specific module offering mini-games (Step by Step, Right Tool Right Process, Memory Game, How It's Made), an interactive quiz video featuring master silversmith Yiannis Mentis demonstrating the Filigree technique, and an interactive quiz video demonstrating the sand casting technique. A progress tracking system indicates completed and pending activities.
- Make an Object (Simulation): A virtual sand-casting simulation allowing users to interactively create a crafted object, conveying the procedural logic of the technique from mould preparation to metal pouring. This module provides a tactile, step-by-step interactive experience of the craft process.
- Evaluate Us: A feedback module enabling visitors to rate and comment on the museum and their experience with the application, using a five-star rating system and open-text fields.
- Settings: An institutional information section providing links to the Silversmithing Museum's website, the Piraeus Cultural Foundation, the Institute of Computer Science at FORTH, and the application's terms and conditions.

A side navigation menu, accessible from any screen, allows users to jump directly to any of the four functional sections, bypassing the linear main menu flow. The application supports bilingual operation (Greek and English), with language selection available from the main menu and the side panel. All content is bundled locally within the application package, enabling fully offline use without dependence on museum Wi-Fi or cellular connectivity.

The application was developed in two phases. The first version established the core navigation structure, the Techniques Museum Tour with its three stations, the initial set of mini-games (two per technique), the simulation module, and the evaluation component. The second version expanded the interactive content with an interactive quiz video for the Filigree technique, additional mini-games (increasing to approximately four per technique), instructional content for the Traditional Craft Centre of Ioannina with Google Maps integration, and a redesigned evaluation flow that separated museum and application feedback.

Figure 3 shows the high-level architecture of the application. On the first layer, the representation of the physical craft environment and the representative user base provide the context

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upon which this research work is built. The second layer regards the data representation for the craft instance, spanning from process documentation to multimodal media assets, all semantically represented and stored. The Rest API gateway ensures seamless access to this knowledge store. The top level of the architecture represents the application layer delivered through the mobile app and web-based alternatives.

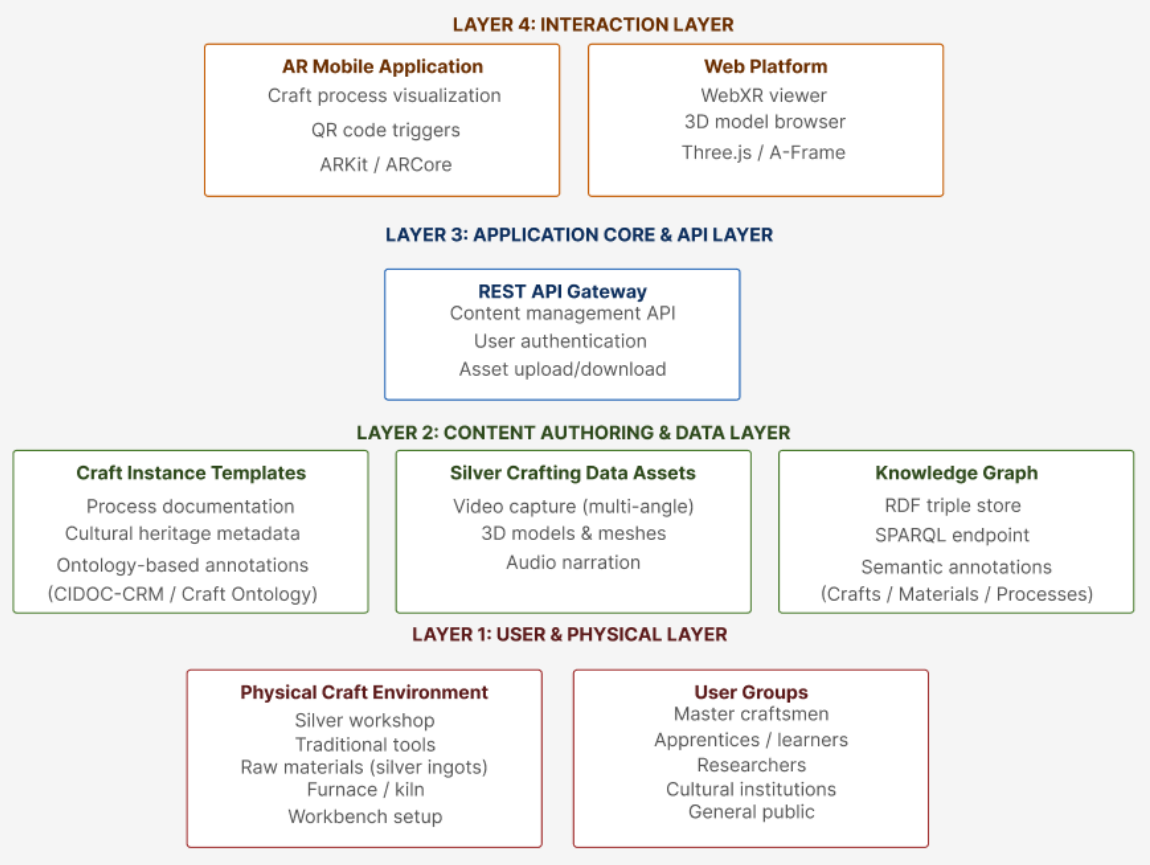

Figure 3. System Architecture - High-Level Overview.

The interaction design and functional details of each module are presented in Section 3.4. The technical implementation of the system, including the development platform, UI design workflow, audio and video production, and deployment, is described in detail in Section 3.5.

3.4. Interaction Design and Functional Modules

Shine Bright Like Silver was developed using the Unity Engine as the primary development platform, targeting Android smartphones and tablets. Unity was selected for its cross-platform capabilities and its support for interactive 2D and 3D content creation through a visual editor combined with C# scripting. The application was designed for self-guided use within the museum context, requiring no staff intervention or device provisioning. The first version supported bilingual operation (Greek and English), delivered interactive content tied directly to the Silversmithing Museum's exhibits, and functioned fully offline, with all multimedia assets embedded locally. The application's structure comprises five core sections accessible from the main menu: Techniques Museum Tour, Interactive Learning Material, Make an Object (simulation), Evaluate Us, and Settings (see Figure 4).

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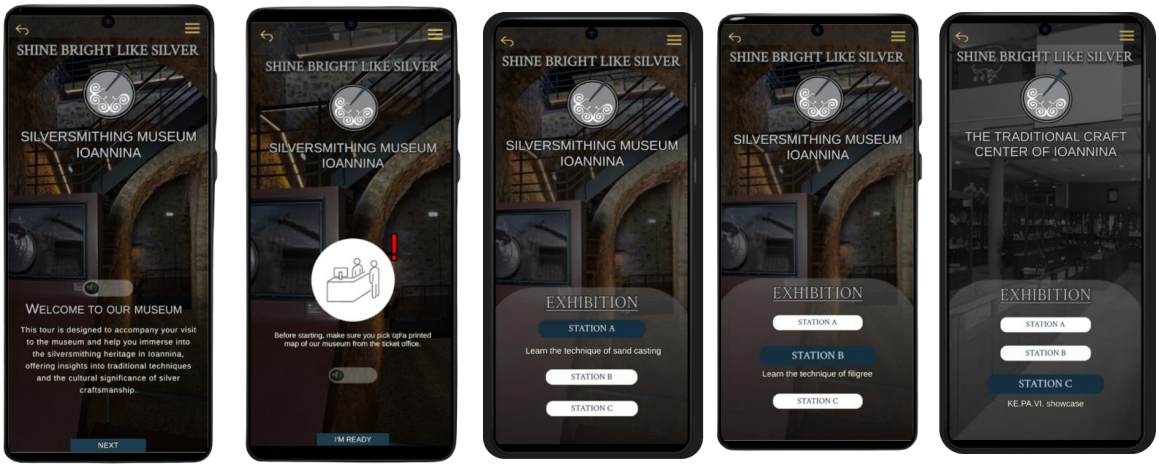
Figure 4. Main Menu - Overview of the Five Core Sections.

3.4.1. Techniques Museum Tour

The Techniques Museum Tour guides visitors through three exhibition stations corresponding to distinct aspects of the silversmithing tradition: (A) Sand Casting, (B) Filigree, and (C) the Traditional Craft Centre of Ioannina (KE.PA.VI.). Upon launching the tour, users are presented with an introductory screen explaining the purpose of the experience and are advised to collect a printed map from the museum's ticket office to orient themselves within the physical exhibition space.

Navigation between the three stations is supported by a station-selection screen, where each station is represented by a button accompanied by a background image drawn from the museum or the KE.PA.VI. exhibition area. The interface maintains a consistent visual identity throughout, including the museum logo, application title, back-navigation arrow, and a side-menu icon accessible from both upper corners. An audio playback button provides AI-generated narration of on-screen text, supporting accessibility and visitors who prefer auditory engagement (see Figure 5).



(a) - Introductory Screens (b) - Station Selection Screens

Figure 5. Techniques Museum Tour: (a) - Introductory Screens, (b) - Station Selection Screens.

Station A (see Figure 6): Sand Casting introduces the traditional sand-casting technique. Users are prompted to visit the corresponding physical exhibition area to read the display text, watch the technique video, and examine the tools on site. Three interactive games are offered: Step by Step, which requires users to arrange the process steps of sand casting in the correct order; Memory Game, a card-matching activity featuring tools and procedural elements; and How It's Made, a sorting task in which users place each tool or technique element in the appropriate category. A progress indicator marks completed games with green checkmarks, while pending activities remain visually distinct.

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Figure 6. Station A - Sand Casting Introduction and Interactive Games.

Station B (see Figure 7): Filigree combines physical exhibition engagement with a digital interactive video experience. Users are first instructed to explore the corresponding exhibition area, reading informational text and observing tools and silver components. A contextual highlight directs attention to a key exhibit (a Miniature Chest) and prompts users to scan a QR code on the physical display to access the biography of the artisan Yannis Mentis, who appears in the demonstration video. Before entering the interactive video mode, users are prompted to rotate their device into landscape orientation. The interactive video presents embedded questions at intervals throughout the demonstration; users select from multiple-choice answers, receive immediate feedback (correct answers highlighted in green, incorrect in red), and view a results summary at the end showing their score across all questions. Navigation controls (Skip, Go Back) are available at all times.

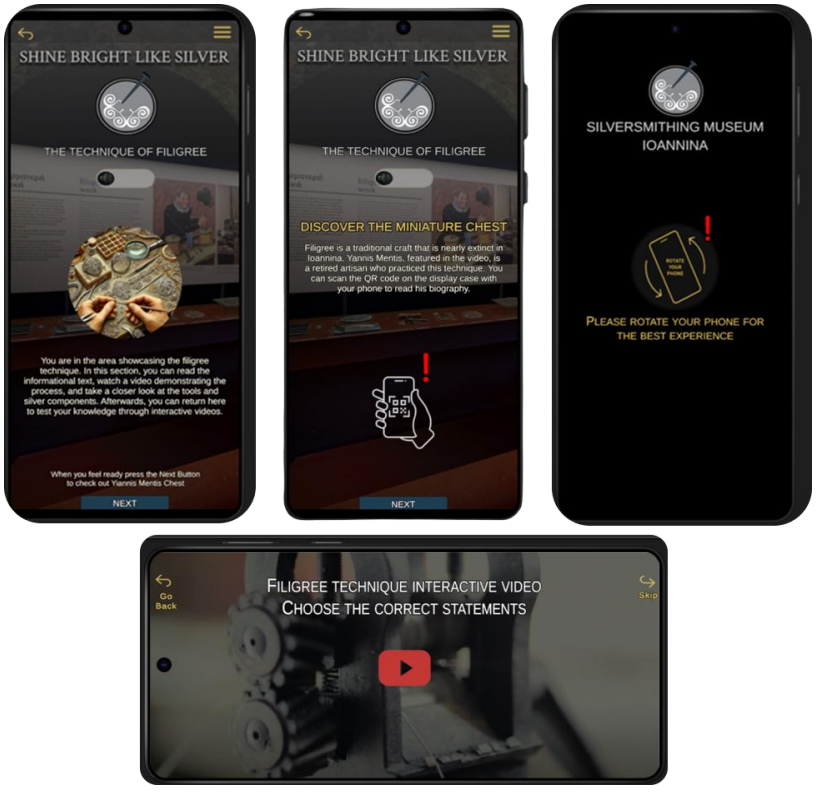

Figure 7. Station B - Filigree Technique Flow (Introduction, QR Guidance, Orientation, Interactive Video).

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Station C (see Figure 8): Traditional Craft Centre of Ioannina introduces KE.PA.VI. as a multi-purpose cultural and commercial hub hosting workshops, exhibitions, events, and a retail shop for handmade silversmithing products. This section is accessible after users have completed all three museum stations. The closing screen presents three options: navigate to instructions for KE.PA.VI., proceed to the Evaluate Us section, or return to the home screen. The KE.PA.VI. information screen provides the full address, opening hours, and a button that opens the location directly in Google Maps.

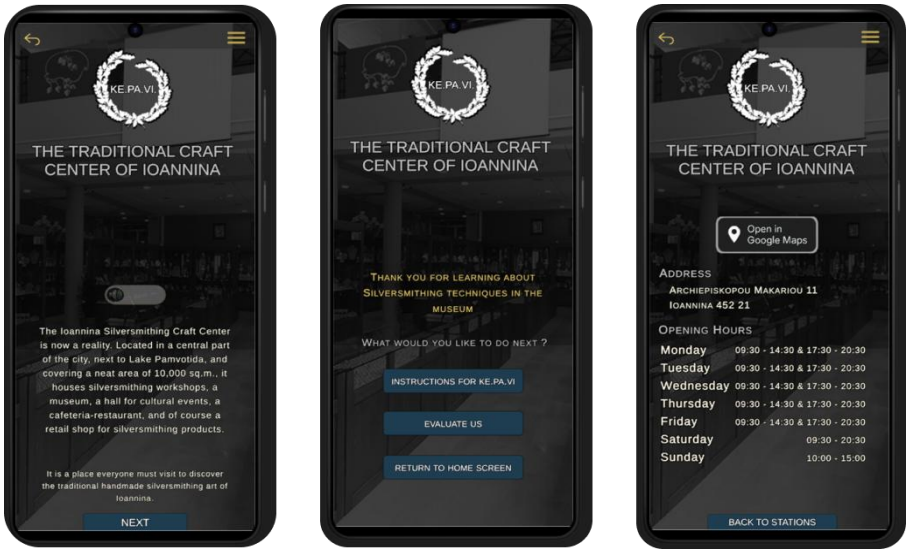
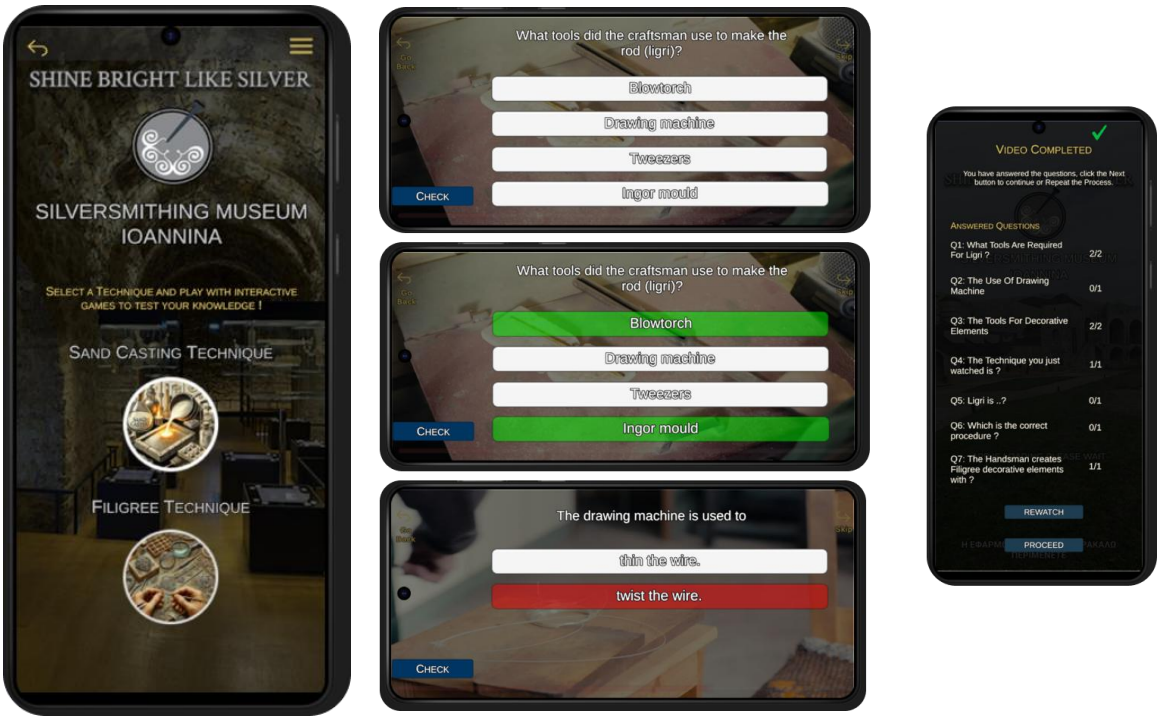


Figure 8. Station C - Traditional Craft Centre of Ioannina Flow.

3.4.2. Interactive Learning Material

The Interactive Learning Material section provides technique-specific mini-games and interactive video content that allow users to test and deepen their understanding of silversmithing processes. Users enter this section by selecting one of two techniques (Sand Casting or Filigree), each represented by a circular icon on the selection screen (see Figure 9).



(a) - Technique Selection (b) - Interactive Video – Design & Functionality

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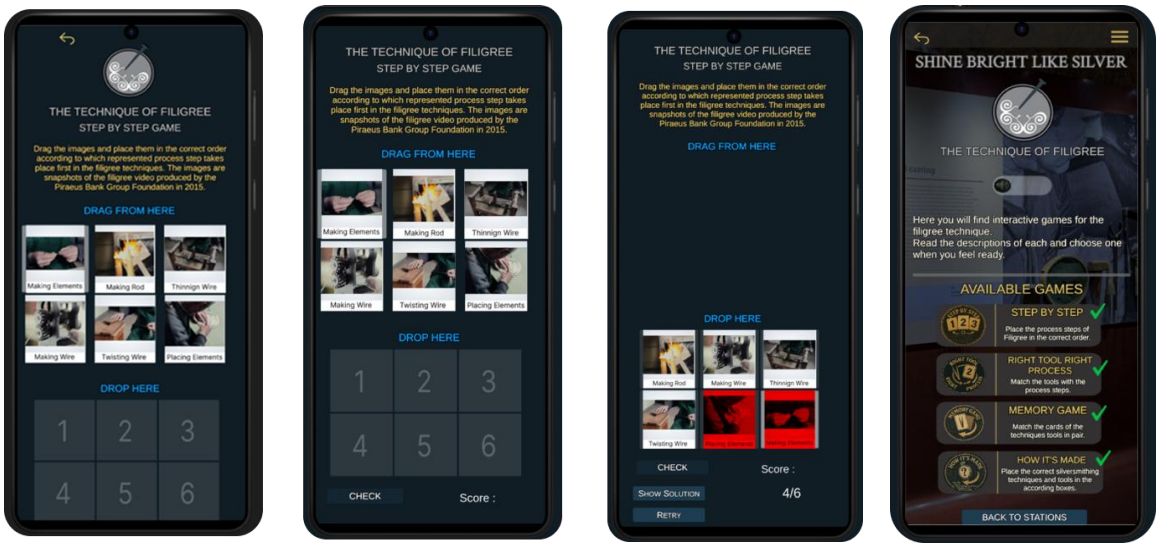

(c) - Step-by-Step Game (Filigree)

(d) - Games Completion Status

Figure 9. Games overview: (a) Technique Selection, (b) Interactive Video – Design & Functionality, (c) Step-by-Step Game (Filigree), (d) Games Completion Status.

For each technique, a set of mini-games is available, increasing from two activities per technique in the first version to approximately four in the second. The games include:

- Step by Step: Users arrange still frames, captured from the official technique video, into the correct chronological order of the craft process. Images are dragged into numbered slots; upon submission, correctly placed images retain their normal appearance while incorrect placements are highlighted in red. Users may retry or view the correct solution.
- Right Tool Right Process: A classification task in which users match tools to the procedural stage in which they are used.
- Memory Game: A card-matching activity pairing tools and procedural elements.
- How It's Made: A sorting task requiring users to place technique elements into appropriate categories.

A progress tracking system displays all available games for the selected technique, with green checkmarks indicating completed activities and unmarked entries indicating pending ones. A Back to Stations button allows users to return to the station-selection menu at any point.

The interactive video component features master silversmith Yiannis Mentis demonstrating the Filigree technique. The video pauses at intervals to present comprehension questions with multiple-choice answers. Users receive immediate feedback and, upon completion, view a summary of their performance across all questions (7 total). The results screen offers two options: re-watch the video or proceed to the Filigree mini-games. The interactive video was produced using Lumi, an open-access tool for creating educational content, which enabled the integration of quiz elements into audio-visual material derived from the museum exhibition.

3.4.3. Sand Casting Simulation

The Make an Object section provides a virtual sand-casting simulation in which users can interactively create a crafted object. This module was developed to convey the procedural logic of the sand-casting technique, from preparing the mold to pouring the molten metal, through a guided, step-by-step interactive experience. The simulation is accessible from the main menu and via the Techniques Museum Tour after engaging with Station A. While the original design concept included a VR-based crafting experience, the constraints of the museum deployment environment led to the implementation of a touchscreen-based simulation that requires no additional hardware or staff support.

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3.5. Technical Architecture and Implementation

Shine Bright Like Silver is a native Android application using the Unity Engine (version 2021.3 LTS) as the core development platform. Unity was selected for its cross-platform rendering pipeline, its integrated C# scripting environment, and its capacity to support interactive 2D and 3D content within a single project. The application targets Android API level 26 (Android 8.0 Oreo) and above, covering the vast majority of smartphones and tablets currently in use among the target visitor demographic. The final Android package (APK) size is approximately 276 MB, reflecting the inclusion of all multimedia assets such as video, audio, images, and 3D models embedded locally to enable full offline operation.

The application architecture follows a modular scene-based structure, with each of the five main sections (Techniques Museum Tour, Interactive Learning Material, Make an Object, Evaluate Us, and Settings) implemented as a distinct Unity scene. Scene transitions are managed through a central SceneManager component, which handles asset loading, state persistence, and navigation between sections. A persistent GameManager singleton maintains application state across scenes, including language preference, progress tracking (completed games and stations), and feedback submission status.

The user interface was designed in Figma, a collaborative, web-based design tool, where wireframes and interactive prototypes were produced before implementation. The Figma layouts were exported as image assets and re-implemented within Unity using the built-in UI System (Canvas, Panels, Buttons, Image components). This workflow allowed the design team to iterate rapidly on visual layout and interaction patterns in Figma before committing to the Unity implementation. Within Unity, UI elements are organized into nested Canvas hierarchies, with each screen represented as a dedicated Panel containing its own set of interactive components. Navigation flows, including the carousel-based main menu, the station-selection screens, and the side menu overlay, are controlled by dedicated navigation scripts that respond to user input events (such as tap, swipe) and manage screen transitions with animated fades.

Audio content was produced using TTSMP3 (Text-to-Speech MP3), a text-to-speech synthesis tool that generates natural-sounding voice narration from written text. AI-generated narration was created for all instructional text across the application, providing an accessibility layer for visitors with visual impairments or literacy challenges and supporting visitors who prefer auditory engagement. Audio files were exported as compressed MP3 assets and imported into Unity, where they are triggered via dedicated AudioSource components attached to UI buttons. The narration system is fully synchronized with the on-screen text, allowing users to toggle audio playback at any point during their interaction.

Interactive video content was produced using Lumi, an open-access educational content authoring tool that supports the embedding of quiz questions, hotspots, and branching logic within video timelines. Lumi was used to create the interactive Filigree demonstration video featuring master silversmith Yiannis Mentis. The Lumi project was exported as an HTML5 package and, because Unity does not natively support H5P or Lumi file formats, the interactive video logic was re-implemented in Unity as a custom component. Video playback is handled through Unity's VideoPlayer component, with question overlays and answer validation logic implemented as C# scripts that intercept playback at predefined timestamps and present comprehension questions to the user.

The original design concept envisaged the use of H5P-authored interactive content hosted on Craeft's e-learning platform. However, given Unity's lack of native H5P support and the requirement for fully offline operation within the museum environment, all interactive games were developed from scratch within Unity. This decision, while increasing development effort, provided greater control over visual consistency, performance, and the integration of games within the broader application flow.

The application supports bilingual operation (Greek and English), with all textual content stored in localization asset files and swapped at runtime based on user selection. Language preference is

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persisted across sessions via Unity's PlayerPrefs system. The language selection is accessible from the main menu and from the side navigation panel, with flag icons indicating the currently selected language.

Offline functionality was a design requirement, given the museum's limited connectivity infrastructure and the need for the application to function reliably without staff-managed device provisioning. All multimedia assets, including video files, audio narration, images, 3D models, and interactive content, are bundled within the APK and loaded from local storage. No network requests are made during normal operation. The only exception is the Google Maps integration in the KE.PA.VI. section, which opens an external URL that requires connectivity; this link is clearly labelled and is the only feature that depends on external access.

PIOP reviewed and validated the development process, textual content, visual materials, and the design and aesthetics for alignment with the museum's institutional voice and the accuracy of the silversmithing techniques presented. The second development phase incorporated additional interactive material. This included the interactive quiz video and expanded mini-game sets (increasing from two to approximately four activities per technique), based on feedback from internal testing and content review.

The application is a signed Android APK and distributed by direct installation on museum-provisioned devices and via a QR code linking to a download page. The QR code was displayed at the museum entrance and at the ticket office, allowing visitors with their own devices to install the application before or during their visit. Version control was managed through a Git-based repository, with each development milestone tagged and documented. The final release version, along with installation instructions and a user guide, was deposited in the project's open repository on Zenodo.

3.6. Evaluation Design

The evaluation of Shine Bright Like Silver employed a mixed-methods approach, combining a standardized user experience instrument with a custom survey targeting the learning, engagement, and valorization outcomes defined in PIOP's change pathway. The evaluation was conducted on-site at the Silversmithing Museum in Ioannina over two days. This section describes the participants, procedure, instruments and measures, and data analysis approach.

3.6.1. Participants and Recruitment

The evaluation took place on Thursday, 10th and Friday, 11th July 2025, with regular museum visitors recruited as participants. An informative sheet with an installation guide was made available at the ticket area. To avoid connectivity-related disruptions, the application was pre-loaded on six tablets provided by the project team. A PIOP colleague and the museum professional working at the ticket office informed incoming visitors about the application. They invited them to test it during their visit as an accompanying tool targeting specific thematic areas of the museum.

Given the museum's linear visitor route (separate entrance and exit), another PIOP colleague and the museum professional working at the shop collected the tablets and administered the evaluation survey to visitors upon exit. Due to the limited timeframe of the evaluation and the decision to work with regular museum visitors rather than a pre-recruited sample, a formal sampling frame was not prepared. Instead, a convenience sampling approach was adopted, whereby every visitor was invited to participate, and their decision was respected. A total of 26 visitors completed the evaluation.

3.6.2. Procedure

Visitors were approached at the museum entrance and informed about the application and the evaluation. Those who agreed to participate were either given a tablet with the application pre-installed or assisted in installing it on their own device via a QR code linked to the download page.

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Visitors were encouraged to use the application during their museum visit as an accompanying tool, engaging with the content relevant to the exhibition areas they encountered.

Upon completing their visit, participants were asked to complete the evaluation survey, which was administered either on the tablet or on a separate device. The survey was available in Greek and English, matching the language selected in the application. The procedure was designed to minimize disruption to the visitor experience while capturing feedback immediately after the interaction, maximizing the accuracy of self-reported responses.

3.6.3. Instruments and Measures

The evaluation survey comprised two parts, designed to address user experience and the broader impact outcomes defined in PIOP's change pathway, namely, stimulating interest in the craft, transmitting knowledge on techniques, fostering connections to the local and broader craft community, and contributing to the safeguarding of the craft through informal knowledge transmission. These outcomes map to the impact areas of learning, legacy, and the experience economy.

Part A - User Experience Questionnaire (UEQ). The first part of the survey contains the standardized User Experience Questionnaire, a validated instrument for assessing the user experience of interactive products. The UEQ measures six dimensions: attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty. Responses are collected on a 7-point semantic differential scale. Two open-ended questions were appended to the UEQ, "What did you like most?" and "What did you like less?" to capture qualitative feedback. This combined approach (standardized instrument plus open-ended items) has been employed in prior heritage technology evaluations, including within the Horizon 2020 project Mingei.

Part B - Impact and Outcome Measures. The second part of the survey comprises six single-choice questions using a 5-point Likert scale (from "not at all" to "very much"), targeting the desired outcomes:

1. Prior knowledge: Participants' self-assessed knowledge of silversmithing before the museum visit and application use.
2. Learning gain: The extent to which the application helped participants learn more about silversmithing.
3. Future learning intent: The extent to which the application motivated participants to learn more about the craft in the future.
4. Visit intent: The likelihood of visiting other places related to silversmithing as a result of the museum and application experience.
5. Consumption habits: The frequency with which participants purchase craft products while travelling.
6. Purchase intent: The likelihood of purchasing craft products as a result of the museum and application experience.

Two additional questions measured overall satisfaction and recommendation intent. Overall satisfaction was assessed on a 10-point scale (from "extremely dissatisfied" to "extremely satisfied"). Recommendation intent was measured using a net-promoter-style item that asked participants how likely they would be to recommend the application to a friend or family member, on a scale from "not at all likely" to "extremely likely".

Demographics. The survey concluded with demographic questions on country of origin and age group, enabling a basic characterization of the sample.

3.6.4. Data Analysis

Quantitative data from both parts of the survey were analyzed using Microsoft Excel. For the UEQ, the standard analysis procedure was followed: raw scores were converted to dimension scores,

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which were then compared against the UEQ benchmark dataset to determine the application's standing on each of the six dimensions. Results were visualized using the UEQ benchmarking graph.

For Part B, descriptive statistics (frequencies, percentages) were calculated for each survey item. Responses were aggregated across the 5-point scale categories and presented as percentage distributions. Overall satisfaction and recommendation intent scores were summarized using mean and distribution across the respective scales.

Qualitative data from the two open-ended UEQ questions ("What did you like most?" and "What did you like less?") were analyzed using inductive text analysis. Responses were coded thematically, with categories emerging from the data rather than being predetermined. This allowed for the identification of unexpected insights regarding user perceptions of the application and its role within the broader silversmithing ecosystem. Themes were identified across several topics, including general impressions, the museum exhibition, application content, user experience, learning outcomes, and comments specific to the interactive learning material.

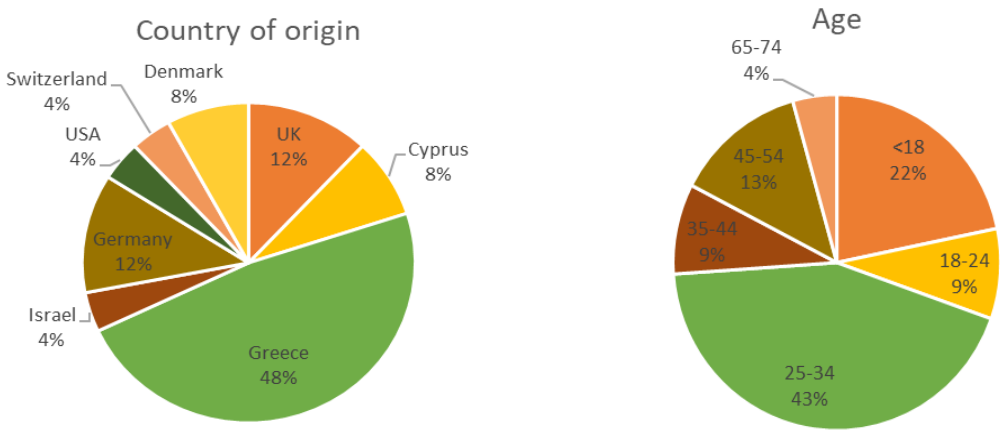
The results of the evaluation are presented in Section 4, structured across four subsections: participant characteristics, UEQ outcomes, quantitative survey results, and qualitative feedback and emergent themes.

4. Results

The evaluation of Shine Bright Like Silver employed a mixed-methods survey designed to address the desired outcomes of PIOP's change pathway: increasing visitors' interest in silversmithing, transmitting knowledge of techniques, strengthening connection to the local and broader craft community, and contributing to the safeguarding of craft knowledge. These outcomes map to three wider impact areas: learning, legacy, and the experience economy. The survey comprised two parts. Part A included the standardized User Experience Questionnaire (UEQ), followed by two open-ended questions. Part B contained six single-choice items on a five-point scale, plus two overall satisfaction measures. The evaluation was conducted on-site at the Silversmithing Museum in Ioannina on 10–11 July 2025. A total of 26 visitors participated.

4.1. Participant Demographics

The sample was international in composition. Nearly half of the participants (48%) were from Greece, while 12% each were from Germany and the United Kingdom. The remainder came from Cyprus, Denmark, Israel, Switzerland, and the United States. In terms of age, the largest group (43%) fell within the 25–34 range. Younger participants (under 18) accounted for 22%, and the 45–54 age group represented 13%.



(a) - Participants' country of origin (b) - Participants' age

Figure 10. (a) Participants' country of origin. (b) Participants' age.

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The international character of the sample and the inclusion of younger and older visitors provided a diverse basis for evaluating the application's performance across different demographic segments.

4.2. User Experience Questionnaire (UEQ)

Analysis of the UEQ data using Microsoft Excel revealed a differentiated profile across the six scales (see Figure 11). The application achieved an excellent score on Attractiveness, indicating that the visual design and overall impression of the interface were strongly positive. Stimulation and Novelty received good scores, suggesting that visitors found the application engaging and sufficiently distinct from conventional museum guides. Perspicuity and Efficiency were rated above average, reflecting a generally clear navigation structure and functional interaction model. Dependability received a negative score; however, this result is not interpretable due to incomplete responses from two participants on items corresponding to this scale.

The benchmarking graph positions the application relative to the UEQ reference database, showing that Attractiveness, Stimulation, and Novelty fall in the upper percentiles. Perspicuity and Efficiency occupy the middle range. The negative Dependability score should be disregarded pending further data collection.

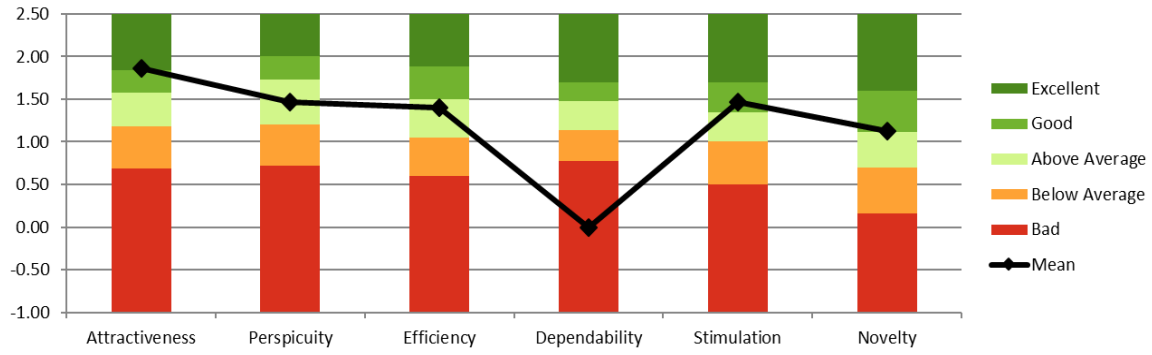

Figure 11. Benchmarking graph of UEQ results.

4.3. Learning Outcomes

Part B of the survey targeted visitors' self-reported knowledge gains. Approximately 70% of participants declared themselves not very knowledgeable about silversmithing before visiting the museum or using the application. After the visit, this shifted markedly: 50% reported they learned somewhat more about silversmithing, and 31% felt they had learned a lot. This represents a clear positive shift in self-perceived knowledge.

Furthermore, 73% of participants (54% somewhat, 19% very much) indicated that the application had increased their desire to learn more about silversmithing in the future. This outcome extends beyond immediate knowledge acquisition to sustained interest, which is a key indicator of effective informal learning in museum contexts (see Figure 12).

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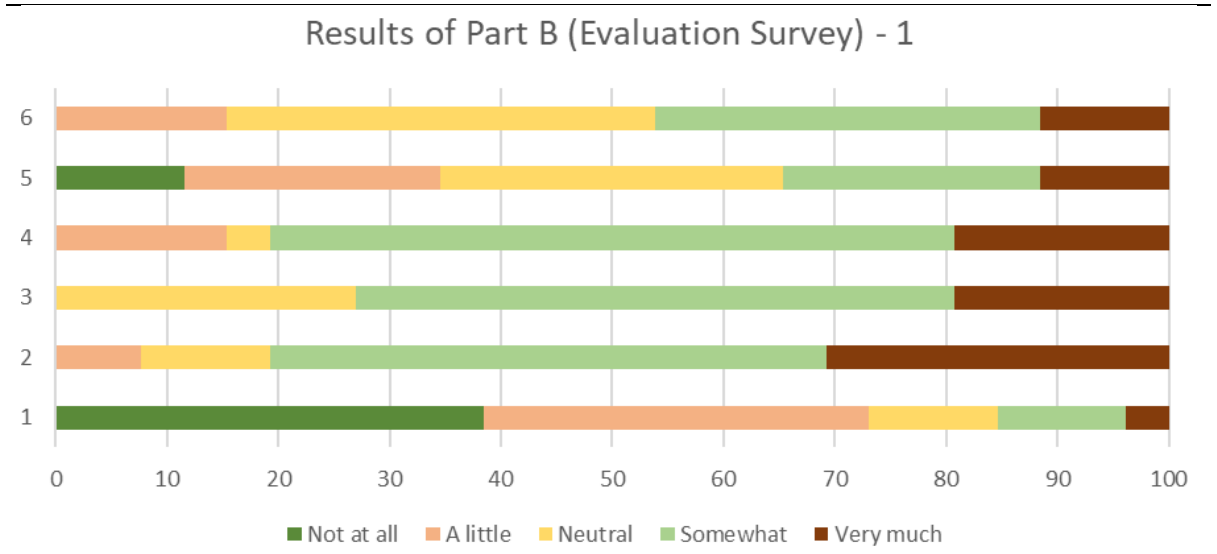

1	How knowledgeable were you about silversmithing before visiting the museum and/or using the application?
2	How much do you think this application helped you learn more about silversmithing?
3	How much do you think this application made you want to learn more?
4	Would you visit other places related to silversmithing as a result of your experience visiting the museum and using the application?
5	How often do you buy craft products while travelling?
6	Would you buy craft products as a result of your experience visiting the museum and using the application?

Figure 12. Results of the evaluation survey's quantitative results.

4.4. Engagement and Experience Economy

Two survey items addressed the experience economy dimension. The first measured participants' craft-related consumption habits while travelling. Responses were distributed across the scale: 31% were neutral, 23% each selected "a little" and "somewhat," and 11% each selected "not at all" and "very much." This suggests that craft consumption while travelling is not a uniform behavior and may depend on individual circumstances and economic factors.

The second item assessed the intention to purchase craft products due to the museum visit and the application. Here, responses were slightly more positive: 38% were neutral, 34% indicated they would "somewhat" buy craft products, 15% responded "a little," and 11% expressed "very high" intention. While purchase intentions were more moderate than learning outcomes, the shift from neutral to affirmative across 60% of respondents suggests that the application had some effect on visitors' economic engagement with the craft.

4.5. Valorisation and Legacy Intentions

Two measures captured valorization-related outcomes. The first assessed participants' intent to visit other places related to silversmithing as a result of their experience. Sixty-one per cent responded that they "somewhat" would, 19% said they "definitely" would, and 15% indicated they "a little" would. This means that 80% of participants expressed at least some intention to extend their engagement with silversmithing beyond the museum visit, which aligns with PIOP's goal of connecting museum audiences to the broader craft ecosystem, including KE.PA.VI.

The second measure assessed legacy through the intention to recommend the application. A strong majority (78%) indicated they would recommend it to friends or family members. This metric is particularly relevant for valorization, as peer recommendation can drive application adoption and, indirectly, engagement with the craft community.

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4.6. Overall Satisfaction

Overall stakeholder satisfaction was measured on a ten-point scale. Nearly 80% of participants declared themselves very satisfied with their experience using the application during the museum visit. This high satisfaction rate, combined with the strong recommendation, indicates that the application was well received.

4.7. Qualitative Feedback

Open-ended questions ("What did you like most?" and "What did you like least?") yielded 54 coded responses, of which 42 were positive and 12 were negative. Text analysis identified comments across six categories: general impressions, the museum exhibition, application content, user experience, learning outcomes, and specific remarks about the interactive learning material.

Positive themes. Participants described the application as interesting, understandable, and original. Several noted that the balance between text and video content was appropriate. The learning outcomes were frequently mentioned, with participants reporting that the application helped them memorize information about techniques and tools, and served as an auxiliary tool for understanding the exhibits. The variety of learning pathways was also appreciated.

The interactive learning material referred to by participants as "games" was particularly popular, especially among younger visitors. The Memory Game was singled out as an effective method for knowledge propagation, and the interactive videos were praised for deepening museum knowledge. The "Place the Process Steps in the Correct Order" activity was noted for directing participants' attention to the exhibition and the visual material. The inclusion of images from the physical exhibition in the digital games was valued for enabling users to track objects across physical and digital formats.

Critical themes. A small number of technical issues were reported, including a malfunction in the interactive learning videos. Some participants found the museum stations not clearly delineated within the application, which created confusion about where specific content was located. One participant reported that using the application during the visit was disorienting, as they struggled to manage text, video, and interactive content; this participant suggested that the application would be better used separately, after the physical visit.

Two participants suggested expanding the content to include historical documents from silversmiths and diagrams representing craft knowledge. Another proposed enhanced interaction with the exhibits through QR codes, graphics, or AR features. One participant noted that there were "many steps" in each technique/station, while another suggested there could be even more, indicating divergent preferences regarding content density.

Two participants also expressed curiosity about the Sand-Casting Simulation module, which was not yet available at the time of the evaluation. The qualitative feedback confirms the quantitative findings: the application was perceived as educational, engaging, and well-designed, with the interactive learning material as its strongest feature. Criticisms were relatively few and focused on technical reliability, navigation clarity, and the challenge of multitasking between the application and the physical exhibition; these issues shall be addressed through iterative design refinements.

4.8. Summary of Findings

The evaluation results indicate that Shine Bright Like Silver achieved its objectives. The UEQ analysis revealed strong performance on Attractiveness, Stimulation, and Novelty, with above-average scores on Perspicuity and Efficiency. The learning outcomes were substantial, with a marked shift from low pre-visit knowledge to high post-visit self-reported learning, and 73% of participants expressed increased desire to learn more. Engagement with the experience economy was more moderate but still positive, particularly regarding purchase intentions. Valorization outcomes were strong, with 80% expressing intent to visit other silversmithing-related sites and 78% willing to recommend the application. Overall satisfaction reached nearly 80%. Qualitative feedback supported

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these findings, highlighting the educational value and interactivity, while identifying a small set of actionable improvements for future iterations.

5. Discussion

This section interprets the evaluation findings in relation to the research questions posed in the introduction, connecting the results to broader debates on heritage valorization, HCI for CH, and reenactable preservation. We discuss the implications of the findings for CH preservation, economic sustainability, and professional development; compare the approach to existing digital heritage methods; and acknowledge limitations and directions for future work.

5.1. Interpretation of Findings

The evaluation results demonstrate that Shine Bright Like Silver achieved its intended purpose as a valorization tool. The application improved access to craft knowledge, generated strong engagement and satisfaction, and created plausible pathways from digital interaction to real-world interest, site visits, and purchase intentions. These outcomes align with PIOP's change pathway and the broader Craeft valorization framework, which treats valorization as an integrated process of making craft knowledge visible, meaningful, and economically viable.

The UEQ results: excellent Attractiveness, good Stimulation and Novelty, above-average Perspicuity and Efficiency, indicate that the application's design successfully mediated between the complexity of silversmithing techniques and the needs of a general museum audience. The strong learning outcomes (70% low pre-visit knowledge shifting to 81% reporting learning gains) suggest that the application effectively transmitted technique-specific knowledge to visitors with no prior familiarity with the craft. This is significant because it demonstrates that digital mediation can reach audiences who most need interpretation, rather than only reinforcing the knowledge of existing craft enthusiasts.

The gamified elements: The Memory Game, the "Place the Process Steps in the Correct Order" activity, and the progress indicator system played a central role in sustaining engagement. Qualitative feedback confirmed that participants, particularly younger visitors, perceived these features as integrated learning tools that helped them memorize techniques and tools. This finding supports the principle that gamification in heritage contexts is most effective when it is grounded in authentic craft content rather than layered on top of it.

The qualitative feedback also revealed a tension that is characteristic of mobile museum applications: the challenge of multitasking between the digital interface and the physical exhibition. One participant reported that using the application during the visit was disorienting, suggesting that the cognitive load of text, video, and interactive content while observing physical exhibits exceeds what some visitors can manage comfortably. This observation points to a design consideration for future iterations: the application could benefit from a "visit mode" (minimal content, focused on exhibit linkage) and a "post-visit mode" (full content, for deeper exploration after the physical visit).

5.2. Implications for Heritage Preservation

The pilot contributes to the safeguarding of intangible CH by keeping craft knowledge attached to authentic contexts: places (the Silversmithing Museum and KE.PA.VI.), people (practicing silversmiths), and processes (tools, materials, sequences). The application communicates the relationships that make silversmithing meaningful, how techniques are embedded in communities, how tools and materials are used in sequence, and why the Ioannina tradition matters historically and culturally.

This approach aligns with the Craeft framework of reenactable preservation, which emphasizes representing craft practices in forms that can guide new learners. Shine Bright Like Silver occupies a specific layer within this framework: it is a public-facing interface that introduces museum audiences to techniques and narratives that can later be deepened through more specialized tools, such as haptic

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simulators or semantic-authoring environments. The strong learning outcomes and the 73% of participants who expressed increased desire to learn more suggest that this intermediary role is effective. The application creates an entry point for sustained engagement with craft knowledge.

The finding that the application works particularly well for visitors without prior knowledge is essential for intergenerational and cross-cultural transmission. In a context where traditional silversmithing faces demographic decline and reduced apprenticeship, digital tools can introduce the craft to new audiences, including international visitors and younger generations, who play a critical role in maintaining the continuity of practice.

5.3. Implications for Economic Sustainability

The experience economy findings, while more moderate than the learning outcomes, are meaningful for the economic sustainability of the craft. The 60% of participants expressing at least some intention to purchase craft products as a result of their experience, and the 80% indicating intent to visit other silversmithing-related sites, suggest that the application can support the economic ecosystem surrounding Ioannina silversmithing.

The retail dimension of valorization, which the application supports indirectly through knowledge transmission and community connection, addresses a real market problem: crafts struggle to compete with mass production without credible ways to communicate authenticity, provenance, and value. By providing structured contextualization of techniques, tools, and processes, the application strengthens the differentiation of handcrafted silver objects and consumer trust, which are prerequisites for fair pricing and sustained demand.

The Experiences dimension also supports the economy indirectly by turning digital engagement into intent to visit workshops, training centers, and related sites. This supports tourism-based income for the local silversmithing ecosystem, extending the economic impact beyond its walls to KE.PA.VI. and other craft-related businesses in Ioannina.

5.4. Implications for Professional Development

The pilot implies the emergence of concrete hybrid roles at the intersection of craft and digital technology. The development and evaluation of Shine Bright Like Silver required collaboration between silversmithing practitioners, museum professionals, HCI researchers, and software developers a pattern that points to the viability of roles such as cultural technology mediators (who work between artisans and institutions), experience designers (who translate craft knowledge into tours, interactive content, and learning media), and digital retail storytellers (who support makers with narratives, assets, and authenticity documentation).

Importantly, these roles are compatible with practitioner-led models that maintain low technical overhead and respect cultural specificity. The application was designed without staff intervention or device provisioning, which is realistic for adoption by museums and craft centers with limited technical resources. This compatibility with existing institutional capacities is a key factor in the sustainability of digital valorization initiatives.

5.5. Comparison to State of the Art

Compared with many existing digital heritage approaches, Shine Bright Like Silver adopts a more practice-aligned and ecosystem-aligned model. Conventional museum applications tend to be object-centered, focusing on catalogue entries, audio descriptions, and static images of individual artefacts. In contrast, the application structures its content around techniques, processes, and the lived practice of silversmithing, helping users understand the craft as situated activity rather than a collection of discrete objects.

The place-based emphasis linking the application to the physical exhibition and to KE.PA.VI. also strengthens tourism valorization in a way that typical museum apps do not. By connecting the

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digital experience to real sites within the silversmithing ecosystem, the application supports a multi-location engagement model that extends the museum's reach beyond its physical boundaries.

In terms of gamification, the application advances beyond one-off "edutainment" by linking playful learning with tangible making practices. The Memory Game, the process-ordering activity, and the progress-tracking system are all grounded in authentic craft content, such as tools, techniques, sequences, etc., rather than abstract game mechanics. This integration of engagement and learning is a meaningful advance over fragmented approaches that treat gamification and content delivery as separate concerns.

The bilingual support and offline functionality address practical constraints that are often overlooked in digital heritage projects. The ability to function without connectivity and to serve both Greek and international visitors makes the application more inclusive and more deployable in contexts where digital infrastructure may be inconsistent.

5.6. Limitations

Several limitations of this study should be acknowledged. First, the sample size (n = 26) is modest, limiting the statistical power of the quantitative analysis and the generalizability of the findings. The evaluation was conducted over two days at a single museum, and participants were self-selected visitors who chose to engage with the application. This may have introduced a positive selection bias.

Second, the evaluation relied primarily on self-reported measures. While the UEQ is a well-validated instrument and the custom survey was designed to align with PIOP's change pathway, self-reported learning and engagement are subject to response biases. Future evaluations could complement self-report data with objective measures, such as pre- and post-knowledge tests or behavioral tracking within the application.

Third, the study did not assess longer-term outcomes. The evaluation captured immediate post-use responses but did not track whether participants subsequently visited KE.PA.VI., purchased craft products, or engaged further with silversmithing content. Longitudinal studies would be needed to determine whether the application's valorization effects persist beyond the museum visit.

Fourth, the application was evaluated in its initial version. The Sand Casting Simulation module was not yet available at the time of the evaluation, and some technical issues (e.g., video malfunctions) were reported. Iterative improvements may address these issues, meaning that the results reflect the performance of a prototype rather than a mature product.

Fifth, the cultural and institutional context of the Ioannina Silversmithing Museum is specific: the museum is relatively small, the craft has deep local roots, and the partnership with KE.PA.VI. provides a clear pathway for valorization. The applicability of the findings to other museum contexts should be interpreted with caution.

5.7. Directions for Future Work

The evaluation results point to several directions for future work. First, the application should undergo iterative refinement, with particular attention to the navigation structure, the Sand Casting Simulation, and the video content reliability. Usability testing with a broader range of participants could identify further improvements.

Second, integrating the application with other Craeft tools should be explored. The project has developed haptic simulators, semantic-authoring environments, and knowledge graphs for craft representation. A connected digital ecosystem, in which the mobile application is an entry point to more specialized tools, could deepen the impact and support more sustained learning trajectories.

Third, the application's content could be expanded to include more narrative and historical material. Qualitative feedback indicated interest in historical documents, diagrams representing craft knowledge, and enhanced interaction with exhibits through QR codes or AR features. Integrating these elements could enrich the application and strengthen the connection between museum visitors and the historical depth of the silversmithing tradition.

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Fourth, the evaluation methodology could be strengthened through longitudinal measures and objective learning assessments. Tracking participants over time and using knowledge tests or behavioral measures would provide more robust evidence of the application's impact on learning and valorization.

Fifth, the "visit mode" / "post-visit mode" distinction suggested by participant feedback could be implemented to reduce the cognitive load of multitasking between the application and the physical exhibition. This would address one of the few critical comments and could improve the overall user experience.

Finally, the approach developed for the Ioannina silversmithing pilot could be adapted to other Representative Craft Instances within Craeft. The modular architecture of the application and the evaluation framework, combining a User Experience Questionnaire, a custom survey, and qualitative feedback, provides a template that could be customized for other crafts, materials, and museum contexts. Comparative evaluations across multiple RCIs would enable a broader understanding of the conditions under which mobile applications can support craft valorization.

6. Conclusions

This paper has presented the design, implementation, and evaluation of Shine Bright Like Silver, a mobile application for visitors to the Silversmithing Museum of Ioannina. The application was produced within the valorization pilot of the Craeft project, which deploys digital tools across eight Representative Craft Instances to support the sustainability of traditional European crafts. The study addressed a gap in the literature concerning integrated, museum-based applications that combine gamified interactive elements, technique-specific content grounded in documented craft practice, and evaluation of learning, engagement, and valorization outcomes.

The evaluation, conducted on-site at the Silversmithing Museum on 10–11 July 2025 with 26 participants, demonstrated that the application achieved its objectives. The UEQ analysis revealed an excellent score for Attractiveness, good scores for Stimulation and Novelty, and above-average scores for Perspicuity and Efficiency. Dependability received a negative score, though this result is not interpretable due to incomplete responses from two participants. Learning outcomes were substantial: approximately 70% of participants entered the museum with low knowledge of silversmithing, and 81% reported learning gains after the visit. 73% of participants expressed an increased desire to learn more about the craft, indicating that the application's effects extend beyond immediate knowledge acquisition to sustained interest.

Engagement was driven by the gamified modules, i.e., the Memory Game, the process-ordering activity, and the progress indicator system, which qualitative feedback confirmed were perceived as integrated learning tools rather than standalone entertainment. The interactive learning material was the most popular feature, particularly among younger visitors, who appreciated the ability to track objects across physical and digital formats.

Valorization outcomes were strong. 80% of participants expressed intent to visit other silversmithing-related sites, and 78% were willing to recommend the application to friends or family members. Overall satisfaction reached nearly 80%. These results indicate that the application is a bridge between museum audiences and the broader silversmithing ecosystem, including KE.PA.VI. and other craft-related businesses in Ioannina.

The findings carry implications for heritage preservation, economic sustainability, and professional development. For heritage institutions, the study demonstrates that mobile applications can contribute to the safeguarding of intangible CH by keeping craft knowledge attached to authentic contexts and by reaching audiences without prior familiarity with the craft. For economic sustainability, the application supports the differentiation of handcrafted objects and the communication of authenticity and provenance, which are prerequisites for fair pricing and sustained demand. For professional development, the pilot implies the emergence of hybrid roles at the intersection of craft and digital technology, including cultural technology mediators, experience designers, and digital retail storytellers.

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Compared to conventional museum applications, which tend to be object-centered and focused on static interpretation, Shine Bright Like Silver adopts a practice-aligned and ecosystem-aligned model. The application structures its content around techniques, processes, and the lived practice of silversmithing, helping users understand the craft as situated activity rather than a collection of discrete objects. The place-based emphasis linking the application to the physical exhibition and to KE.PA.VI. strengthens tourism valorization in a way that typical museum apps do not.

Several limitations were acknowledged: the modest sample size (n = 26), the reliance on self-reported measures, the absence of longitudinal tracking, the unavailability of the Sand-Casting Simulation at the time of evaluation, and the specificity of the institutional and cultural context. These limitations point to directions for future work, including iterative refinement of the application, integration with other Craeft digital tools such as haptic simulators and semantic-authoring environments, expansion of narrative and historical content, implementation of a visit mode and post-visit mode to reduce cognitive load, and comparative evaluations across multiple Representative Craft Instances.

In conclusion, Shine Bright Like Silver demonstrates that a thoughtfully designed mobile application can contribute meaningfully to the valorization of traditional crafts in museum settings. By combining accessible digital content with gamified interaction and evaluation grounded in user experience and heritage outcomes, the application offers a model that can be adapted and extended to support the broader mission of safeguarding and sustaining European craft heritage in the digital age. The Craeft project's multi-dimensional valorization framework, encompassing Experiences, Games, Retail, and Makers, provides a scalable approach for other craft communities seeking to leverage digital tools for preservation, learning, and economic sustainability.

Supplementary Materials: A video recording of the Shine Bright Like Silver - Mobile Application for Silversmithing is available in Zenodo (https://doi.org/10.5281/zenodo.20040593).

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

AR	Augmented Reality
BVI	Balanced Value Impact
CH	Cultural Heritage
CIDOC-CRM	CIDOC - Conceptual Reference Model

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Craeft	Project name — Craft Understanding, Education, Training, and Preservation for Posterity and Prosperity
CrO	Crafts Ontology
DAI-UoM	Department of Applied Informatics, University of Macedonia
EDM	Europeana Data Model
HCI	Human–Computer Interaction
ICH	Intangible Cultural Heritage
ICS-FORTH	Institute of Computer Science, Foundation for Research and Technology Hellas
KE.PA.VI.	Centre for Vocational Training of Ioannina
KR	Knowledge Representation
Lumi	Open-access educational content authoring tool
MDPI	Multidisciplinary Digital Publishing Institute
MR	Mixed Reality
PBLS	Problem-Based Learning Scenarios
PIOP	Piraeus Bank Group Cultural Foundation
RCI	Representative Craft Instance
UEQ	User Experience Questionnaire
UI	User Interface
VR	Virtual Reality

Appendix A. Evaluation Survey Form

The purpose of this questionnaire is to assess the usability and experience of using the museum's application. Your participation is voluntary and anonymous. No personal data will be collected. By submitting this questionnaire, you agree to include your answers in this study. The study is carried out in the context of the Horizon Europe research and innovation program 'Craeft - Craft Understanding, Education, Training, and Preservation for Posterity and Prosperity' (grant agreement no. 101094349). The results of the study will be used for research purposes and the writing of deliverables of the project, and may be published in scientific conferences and journals after statistical processing. For any further details regarding the Craeft project or the present study, please contact Dr Xenophon Zabulis at: zabulis@ics.forth.gr. Thank you for your participation!

PART A

This part of the questionnaire consists of pairs of contrasting characteristics that may apply to this museum application. Express your agreement with an adjective by ticking the circle that most closely reflects your impression.

Example:	attractive	●	○	○	○	○	○	○	unattractive

This response would mean that you rate the application as more attractive than unattractive.

Please mark a circle in every line, even if you are not sure about your agreement with a specific characteristic. Please respond spontaneously to convey your first impression. It is your personal opinion that counts. There is no wrong or right answer!

annoying	○	○	○	○	○	○	○	enjoyable
not understandable	○	○	○	○	○	○	○	understandable
creative	○	○	○	○	○	○	○	dull
easy to learn	○	○	○	○	○	○	○	difficult to learn
valuable	○	○	○	○	○	○	○	inferior
boring	○	○	○	○	○	○	○	exciting
not interesting	○	○	○	○	○	○	○	interesting
unpredictable	○	○	○	○	○	○	○	predictable
fast	○	○	○	○	○	○	○	slow
inventive	○	○	○	○	○	○	○	conventional

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obstructive	○	○	○	○	○	○	○	supportive
good	○	○	○	○	○	○	○	bad
complicated	○	○	○	○	○	○	○	easy
unlikable	○	○	○	○	○	○	○	pleasing
usual	○	○	○	○	○	○	○	leading edge
unpleasant	○	○	○	○	○	○	○	pleasant
secure	○	○	○	○	○	○	○	not secure
motivating	○	○	○	○	○	○	○	demotivating
meets expectations	○	○	○	○	○	○	○	does not meet expectations
inefficient	○	○	○	○	○	○	○	efficient
clear	○	○	○	○	○	○	○	confusing
impractical	○	○	○	○	○	○	○	practical
organised	○	○	○	○	○	○	○	cluttered
attractive	○	○	○	○	○	○	○	unattractive
friendly	○	○	○	○	○	○	○	unfriendly
conservative	○	○	○	○	○	○	○	innovative
What did you like the MOST about this museum application?								
[text]								
What did you like the LEAST about this museum application?								
[text]								

PART B

Please mark the circle that corresponds to your answer in the following questions:

1. How knowledgeable were you about silversmithing before visiting the museum and/or using the application?				
∘ Not at all	∘ A little	∘ Neutral	∘ Somewhat	∘ Very much
2. How much do you think this application helped you learn more about silversmithing?				
∘ Not at all	∘ A little	∘ Neutral	∘ Somewhat	∘ Very much
3. How much do you think this application made you want to learn more?				
∘ Not at all	∘ A little	∘ Neutral	∘ Somewhat	∘ Very much
4. Would you visit other places related to silversmithing as a result of your experience visiting the museum and using the application?				
∘ Not at all	∘ A little	∘ Neutral	∘ Somewhat	∘ Very much
5. How often do you buy craft products while travelling?				
∘ Not at all	∘ A little	∘ Neutral	∘ Somewhat	∘ Very much
6. Would you buy craft products as a result of your experience visiting the museum and using the application?				
∘ Not at all	∘ A little	∘ Neutral	∘ Somewhat	∘ Very much

On a scale of 0 (Not at all likely) to 10 (Extremely likely), how would you rate your overall satisfaction with this application? Circle your answer below.										
Extremely dissatisfied						Extremely satisfied				
0	1	2	3	4	5	6	7	8	9	10

On a scale of 0 (Not at all likely) to 10 (Extremely likely), how likely are you to recommend this application to a friend or a family member? Circle your answer below.										
Extremely likely						Extremely unlikely				
0	1	2	3	4	5	6	7	8	9	10

Country of origin: ___
Age:

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○ < 18	○ 18-24	○ 25-34	○ 35-44	○ 45-55	○ 54-64	○ 65-74	○ 75 +

References

1. Tomiuc, A. Navigating culture: Enhancing visitor museum experience through mobile technologies. From Smartphone to Google Glass. *J. Media Res.* **2014**, *7*, 5–20.
2. Damala, A. Interaction Design and Evaluation of Mobile Guides for the Museum Visit: A Case Study in Multimedia and Mobile Augmented Reality. Ph.D. Thesis, University of Paris-Sud, Paris, France, 2009.
3. Cardoso, P.J.S.; Rodrigues, J.M.F.; Pereira, J. Cultural heritage visits supported on visitors' preferences and mobile devices. In *Universal Access in Human-Computer Interaction*; Springer: Cham, Switzerland, 2020; pp. 3–18.
4. Koo, S.; Kim, J.; Kim, C.; Cha, H.S. Development of an augmented reality tour guide for a cultural heritage site. In *Proceedings of the 2019 ACM on Interactive Surfaces and Spaces*; ACM: New York, NY, USA, 2019; pp. 1–6.
5. Boboc, R.G.; Băutu, E.; Gîrbacia, F.; Popovici, N. Augmented reality in cultural heritage: An overview of the last decade of applications. *Appl. Sci.* **2022**, *12*, 9859.
6. Hammad, R.; Ma, M.; Powell, A. User experience of markerless augmented reality applications in cultural heritage museums: 'museumeeye' as a case study. In *Augmented Reality, Virtual Reality and Computer Graphics*; Springer: Cham, Switzerland, 2018; pp. 211–224.
7. Othman, M.K.; Nogolbaeva, A.; Leong, L.S. Usability evaluation of a virtual reality smartphone app for a living museum. In *Universal Access in Human-Computer Interaction*; Springer: Cham, Switzerland, 2022; pp. 381–396.
8. Marto, A.; Goncalves, A. Mobile AR: User evaluation in a cultural heritage context. *Appl. Sci.* **2019**, *9*, 2307.
9. Psomadaki, O.I.; Dimoulas, C.A.; Kalliris, G.M. Digital storytelling and audience engagement in cultural heritage management: A collaborative model based on the Digital City of Thessaloniki. *J. Cult. Herit.* **2019**, *40*, 238–247.
10. Sun, Y.; Dong, F. Digital storytelling and narratives in cultural heritage sites: A case study on interactive museum experience design. In *International Conference on Human-Computer Interaction*; Springer: Cham, Switzerland, 2025.
11. Lalopoulos, C.; Konstantakis, M. Designing a mobile digital application for the Museum of Asia Minor Culture: Enhancing intangible cultural heritage through digital storytelling. In *CAA International Conference Proceedings*; CAA International, 2025.
12. Economou, M.; Young, H. Digital storytelling for emotional engagement in museums: Design and evaluation of the Hunterian Antonine Wall EMOTIVE experiences. *J. Herit. Tour.* **2025**. DOI: 10.1080/13527258.2025.2591613.
13. Vrettakis, E.; Kourtis, V.; Katifori, A.; Karvounis, M. Narrative: Creating and experiencing mobile digital storytelling in cultural heritage. In *Digital Cultural Heritage*; Elsevier: Amsterdam, The Netherlands, 2019; pp. 3–17.
14. Kusnick, J.; Mayr, E.; Seirafi, K.; Beck, S.; Liem, J.; Windhager, F. Every Thing Can Be a Hero! Narrative Visualization of Person, Object, and Other Biographies. *Informatics* **2024**, *11*, 26.
15. Paliokas, I.; Patenidis, A.T.; Mitsopoulou, E.E.; Tsita, C.; et al. A gamified augmented reality application for digital heritage and tourism. *Appl. Sci.* **2020**, *10*, 3875.
16. Khan, I.; Melro, A.; Amaro, A.C. Systematic review on gamification and cultural heritage dissemination. *J. Digit. Media Policy* **2020**, *11*, 195–213.
17. Marques, C.G.; Pedro, J.P.; Araújo, I. A systematic literature review of gamification in/for cultural heritage: Leveling up, going beyond. *Heritage* **2023**, *6*, 2608–2634.
18. Nofal, E.; Panagiotidou, G.; Reffat, R.M. Situated tangible gamification of heritage for supporting collaborative learning of young museum visitors. In *Proceedings of the 2020 ACM on Interactive Surfaces and Spaces*; ACM: New York, NY, USA, 2020.
19. Tongpaeng, Y.; Nobnop, R.; Wongwan, N. Comparison of gamified and non-gamified mixed reality in enhancing museum visitor engagement, motivation, and learning outcome. *J. Herit. Tour.* **2024**.

 doi:10.20944/preprints202605.0451.v1

20. Galindo-Durán, A. Enhancing artistic heritage education through gamification: A comparative study of engagement and learning outcomes in local museums. *Nusant. J. Behav. Soc. Sci.* **2025**, *4*.
21. Chatsiopoulou, A.; Michailidis, P.D. Augmented reality in cultural heritage: A narrative review of design, development and evaluation approaches. *Heritage* **2025**, *8*.
22. Srdanović, P.; Skala, T.; Maričević, M. Inheritage—A gamified mobile application with AR and VR for cultural heritage preservation in the metaverse. *Appl. Sci.* **2024**, *14*, 1550.
23. Philippopoulos, P.I.; Drivas, I.C.; Tselikas, N.D.; et al. A holistic approach for enhancing museum performance and visitor experience. *Sensors* **2024**, *24*, 1543.
24. Tesoriero, R.; Gallud, J.A.; Lozano, M. Enhancing visitors' experience in art museums using mobile technologies. *Inf. Syst. Front.* **2014**, *16*, 241–259.
25. Bayeck, R.Y. Board games and learning: Why care in the digital age? In *Learning and Education in the Digital Age*; IntechOpen: London, UK, 2018. DOI: 10.5772/intechopen.72186.
26. Camuñas-García, D.; Cáceres-Reche, M.P.; Cambil-Hernández, M.D.L.E.; Lorenzo-Martín, M.E. Digital game-based heritage education: Analysing the potential of heritage-based video games. *Educ. Sci.* **2024**, *14*, 396. DOI: 10.3390/educsci14040396.
27. Kang, X.; Ying, Y.; Lin, X.; He, K.; Li, X.; Bai, X. Research on the application of gamified learning of traditional bamboo papermaking skills in the dissemination of intangible cultural heritage. In *Proceedings of the 2024 5th International Conference on Mental Health, Education and Human Development (MHEHD 2024)*; Atlantis Press: Paris, France, 2024; pp. 526–532. DOI: 10.2991/mhehd-24.2024.78.
28. Lin, C.F.; Chen, Y.R.; Shih, R.C. Effects of technology-enhanced board game in primary mathematics education on students' learning performance. *Appl. Sci.* **2022**, *12*, 11356. DOI: 10.3390/app122211356.
29. Mendes, J.; Correia, J. Playing at the school table: Systematic literature review of board, tabletop, and other analogue game-based learning approaches. *Front. Psychol.* **2023**, *14*, 1160591. DOI: 10.3389/fpsyg.2023.1160591.
30. Phongsophol, K.; Charoenkitkarn, N.; Raksapetch, B. The game of heritage: Enhancing virtual museum visits through gamification for tourists. *TEM J.* **2024**, *13*, 3359–3372. DOI: 10.18421/TEM134-70.
31. Sulaiman, R.S.A.; Samsudin, M.R. Designing children's traditional games through visual thinking in the socio-cultural concept. *Int. J. Acad. Res. Bus. Soc. Sci.* **2022**, *12*, 2364–2373. DOI: 10.6007/IJARBSS/v12-i10/15535.
32. Varli, G.; Varli, A.; Baki, Y. Experiencing cultural heritage through gamification. In *Proceedings of the 41st eCAADe Conference*; Graz University of Technology: Graz, Austria, 2023; Vol. 1, pp. 211–218.
33. Yang, F. Exploring the role of information systems in documenting tacit knowledge and driving transformation in traditional handicrafts. *Int. J. e-Bus. e-Gov.* **2024**, *16*.
34. Gelvez, J.A.M.; Gualdron, C.I.L. Reference framework for tacit knowledge in craft-based manufacturing processes for updating their practices with digital interventions: A systematic review. In *Proceedings of The European Conference on Arts, Design & Education 2022*; 2022; pp. 559–573. DOI: 10.22492/issn.2758-0989.2022.43.
35. Zabulis, X.; Partarakis, N.; Manikaki, V.; Demeridou, I.; et al. A digitally enhanced ethnography for craft action and process understanding. *Appl. Sci.* **2025**, *15*, 5408. DOI: 10.3390/app15105408.
36. Flanagan, P.J.; Fraietta, A. Tracing the intangible: The curious gestures of crafts' cultural heritage. In *Adjunct Proceedings of the 2019 ACM Conference on Human Factors in Computing Systems*; ACM: New York, NY, USA, 2019.
37. Dubé, P.R. Haptic knowledge: Artisanal skills, labour, and embodied knowledge practices. In *Crafting India's Skill Ecology*; Taylor & Francis: Abingdon, UK, 2025; pp. 138–162.
38. Zhang, X. Skill motion recognition and digital modeling of intangible cultural heritage for smart cities based on computer vision. In *Proceedings of the Conference on Intelligent Transportation and Smart Cities*; SPIE: Bellingham, WA, USA, 2025.
39. Kajtazi, K. AR-Supported Knowledge Transfer: Motion Tracking and Process Visualization for Tacit Knowledge Capturing. Master's Thesis, TU Wien, Vienna, Austria, 2025.
40. Prabhu, V.A. A framework for digitisation of manual manufacturing task knowledge using gaming interface technology. Ph.D. Thesis, Cranfield University, Cranfield, UK, 2015.

 doi:10.20944/preprints202605.0451.v1

41. Aktas, B.; Mäkelä, M. Negotiation between the maker and material: Observations on material interactions in felting studio. *Int. J. Des.* **2019**, *13*, 1–18.
42. Hawkins, H.; Price, L. (Eds.) *Geographies of Making, Craft and Creativity*; Routledge: Abingdon, UK, 2018.
43. Desmarais, S. Affective Materials: A Processual, Relational, and Material Ethnography of Amateur Group Crafts Practice in Two Arts-for-Health Settings. Ph.D. Thesis, University of Sheffield, Sheffield, UK, 2016.
44. Stoyanova, S.; Eide, Ø.; Türkoğlu, E. Modeling Cultural Heritage Materials for Discovery and Analysis. In *The Companion to Digital Humanities in Archaeology and Heritage*; Brouwer Burg, M., Ed.; Taylor & Francis: London, UK, 2025; pp. 234–249.
45. Doerr, M.; Gradmann, S.; Hennicke, S.; Isaac, A.; Meghini, C. The Europeana Data Model (EDM): Object Representations, Context and Semantics. Available online: https://lirias.kuleuven.be (accessed on 15 March 2026).
46. Cui, C.D.L.; Simeone, D.; Fioravanti, A. Modelling and Managing Built Heritage Knowledge: An Ontology-Based Approach for Multi-Layered Archaeologies and Historical Production Process Representation. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* 2023, *XLVIII-M-2*, 205–212. Available online: https://iris.uniroma1.it (accessed on 15 March 2026).
47. Partarakis, N.; Koutlemanis, P.; Demeridou, I. Externalizing Tacit Craft Knowledge Through Semantic Graphs and Real-Time VR Simulation. *Electronics* 2026, *15*, 456.
48. Makris, A.; Demeridou, I.; Koutlemanis, P. A Knowledge Graph-Driven Interactive 3D Simulation for Craft Training. In *Proceedings of the Joint Conference on Digital Libraries (JCDL 2025)*; Springer: Cham, Switzerland, 2025; pp. 112–120.
49. Doulgeraki, P.; Partarakis, N.; Adami, I.; Demeridou, I. Digitisation of Traditional Craft Processes. Available online: https://www.academia.edu (accessed on 15 March 2026).
50. Jose, J.; Unikrishnan, R.; Marshall, D. Haptics-Enhanced Multi-Tool Virtual Interfaces for Training Carpentry Skills. In *Proceedings of the 2016 IEEE International Conference on Robotics and Automation (ICRA)*; IEEE: Piscataway, NJ, USA, 2016; pp. 3421–3426.
51. Väpenstad, C.; Hofstad, E.F.; Bø, L.E.; Kuhry, E. Lack of Transfer of Skills after Virtual Reality Simulator Training with Haptic Feedback. *Invasive Ther. Allied Technol.* 2017, *26*, 161–168.
52. Patel, M.H. Enhancing Virtual Reality Training with Haptic Feedback: A Taxonomy of Devices and Development of a Tactile Interface for VR-Based Manufacturing Training. Ph.D. Thesis, University of Manchester, Manchester, UK, 2023.
53. Hui, L.; Nasir, N.M. Digital Reimagining of Chinese Ceramic Art: The Influence of Emerging Technologies on Creative Practices and Cultural Continuity; City University Press: Hong Kong, China, 2026.
54. Kraatari, E.; Holmberg, L.; Vuijlsteke, C.; Consult, I.; Peters, T. Crafts-Led Innovation; EKIPengine: Tampere, Finland, 2026. Available online: https://ekipengine.eu (accessed on 15 March 2026).
55. McGhugh, C. 'I've Not Finished': Why Studios Are Still a Fundamental Requirement in the Study of Fine Art. *J. Vis. Art Pract.* 2014, *13*, 167–180.
56. Huang, S.Y. The New Materiality of Naturalised Architecture. Available online: https://www.researchgate.net (accessed on 15 March 2026).
57. Kelly, M. The Representation of Interpretative Knowledge in Cultural Heritage Research. Ph.D. Thesis, University of Brighton, Brighton, UK, 2023.
58. Zabulis, X.; Partarakis, N.; Bartalesi, V.; Pratelli, N. Multimodal Dictionaries for Traditional Craft Education. *Multimodal Technol. Interact.* 2024, *8*, 38.
59. Wei, T. Terminology and Ontology for Cultural Heritage: Application to Chinese Ceramic Vessels. Available online: https://the-ses.hal.science (accessed on 15 March 2026).
60. Zabulis, X.; Partarakis, N.; Meghini, C.; Dubois, A. A Representation Protocol for Traditional Crafts. *Heritage* 2022, *5*, 3834–3859.
61. Zabulis, X.; Partarakis, N.; Meghini, C.; Kaplanidi, D. What Is Needed to Digitise Knowledge on Heritage Crafts. *Memoria Ric.* 2019, *63*, 135–152.
62. Partarakis, N.; Zabulis, X.; Antona, M. Transforming Heritage Crafts to Engaging Digital Experiences. In *Visual Computing for Cultural Heritage*; Springer: Cham, Switzerland, 2020; pp. 183–202.

 doi:10.20944/preprints202605.0451.v1

63. Isa, W.M.W.; Zin, N.A.M.; Rosdi, F.; Sarim, H.M. An Ontological Approach for Creating a Brassware Craft Knowledge Base. In *Proceedings of the 2020 IEEE International Conference on System Science and Engineering (ICSSE)*; IEEE: Piscataway, NJ, USA, 2020; pp. 1–6.
64. Partarakis, N.; Doulgeraki, P.; Karuzaki, E. A Web-Based Platform for Traditional Craft Documentation. *Multimodal Technol. Interact.* 2022, *6*, 94.
65. Molee, A.P.; Charuphanthuset, T.; Kunnu, W. Ontology-Based Digital Preservation Framework for Phum Riang Silk Heritage. *Informatics* 2026, *13*, 12.
66. Liang, Y.; Xie, B.; Tan, W.; Zhang, Q. Ontology-Based Construction of Embroidery Intangible Cultural Heritage Knowledge Graph: A Case Study of Qingyang Sachets. *PLoS ONE* 2025, *20*, e0315789.
67. Zabulis, X.; Partarakis, N.; Demeridou, I.; Doulgeraki, P. A Roadmap for Craft Understanding, Education, Training, and Preservation. *Heritage* 2023, *6*, 1–24.
68. Demeridou, I.; Dubois, A.; Kaplanidi, D.; Manitsaris, S. Enhanced Ethnographic Methods; Craeft Deliverable D2.1; Craeft Project: Brussels, Belgium, 2022. Available online: https://craeft.eu (accessed on 15 March 2026).
69. Ye, Y. Immersive Motor Skill Learning Using Haptic Sensation Transfer in Construction. Ph.D. Thesis, University of Washington, Seattle, WA, USA, 2024.
70. Lopez, J.; Bhandari, S.; Perry, L.; Ayer, S.K. Analyzing the Impact of Virtual Reality and Haptic Feedback on the Safety Skills of Construction Workers. *J. Constr. Eng. Manag.* 2025, *151*, 04025012.
71. Ipsita, A. Empowering Experts in Crafting Virtual Reality Training Instructions for Manufacturing Education. Ph.D. Thesis, University of Cincinnati, Cincinnati, OH, USA, 2025.
72. Ji, H.; Hu, P.; El-Zanfaly, D. Reshaping Craft Learning: Insights from Designing an AI-Augmented MR System for Wheel-Throwing. In *Proceedings of the 2025 ACM Designing Interactive Systems Conference (DIS '25)*; ACM: New York, NY, USA, 2025; pp. 845–858.
73. Verwayen, H.; Fallon, J.; Schellenberg, J.; Kyrou, P. *Europeana Impact Playbook*; Europeana Foundation: The Hague, The Netherlands, 2022. Available online: https://europeana.atlassian.net/wiki/spaces/CB/pages/2260566017 (accessed on 5 May 2026). CC BY-SA.