Understanding the properties and dynamics of digitally fabricated replicas in cultural heritage experiences for different audience groups

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Abstract

This thesis explores *digitally fabricated artefacts* or *replicas* and investigates their contribution as novel interpretative means in cultural heritage (CH) experiences for different audience groups. The research adds to a novel body of *knowledge* and *practice* that intersects *cultural heritage*, *computing*, *product design* and their related disciplines, as well as the actual process of *making* as facilitated by digital fabrication.

Given the popularity and increasing accessibility to 3D imaging and 3D printing, replicas are being deployed more to support audience interpretation through multisensorial interactions with physical artefacts, which sometimes act as physical interfaces triggering digital content. However, a lack of understanding of the different factors which define the adoption of replicas for such purposes still exists. This research systematically addresses this gap by introducing the *Replica Experience Framework (RXF),* which "breaks down" replicas and "decodes" their role within CH experiences.

By employing the RXF and by adopting the case study approach, three digitally fabricated replicas were developed in collaboration with the Royal Pavilion and Museums, Brighton & Hove. These were "tested" with three audience groups: visually impaired people, random adult visitors and families. Both qualitative and quantitative methods were used, including creative methods, to gather visitors' feedback. The findings of the research suggest that not only should replicas feel as close as possible to their original artefacts, but they also need to be contextually informed, honestly exhibited and interpreted too, in order to maximise their potential. The research argues that digitally fabricated artefacts deformalise, add significant value, and contribute to "authentic" CH experiences; while enabling audiences to develop a deeper understanding and establish new relationships with CH collections. Yet, in order to successfully integrate replicas in CH interpretation, stakeholders should take into account some of the main contributions of this thesis: the concept of the RXF and guidance on how to deploy it; recommendations for designing, incorporating and researching digitally fabricated artefacts; as well as a well-rounded set of methods as demonstrated by the research to holistically evaluate replicas within CH experiences.

Keywords: digitally fabricated artefacts, digital fabrication, replicas, 3D printing, evaluation, museums, audience research, multisensorial experiences, interpretation

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List of acronyms

2D - Two dimensional

3D - Three dimensional

AI - Artificial Intelligence

BAME - Black, Asian and Minority Ethnic

BLE - Bluetooth Low Energy

BMAG - Brighton Museum and Art Gallery

CAD - Computer-aided Design

CAM - Computer-aided Manufacturing

CEM - Computing, Engineering and Mathematics

CERB - Centre for Education and Rehabilitation for the Blind

CGAL - Computational Geometry Algorithms Library

CH - Cultural Heritage

CREC - Cross-School Research Ethics Committee

CSG - Constructive Solid Geometry

CSIUS - Centre of Secure, Intelligent and Usable Systems

GLAM - Galleries, Libraries, Archives, Museums

HCI - Human Computer Interaction

ICOM - International Council of Museums

IT - Information Technology

MIT - Massachusetts Institute of Technology

NFC - Near-field Communication

OS - Operating System

QR codes - Quick Response Code

RPM - Royal Pavilion and Museums, Brighton & Hove

RXF - Replica Experience Framework

SDK - Software Development Kit

UoB - University of Brighton

UX - User Experience

List of publications

Peer reviewed journal papers

Rodriguez Echavarria, K., & **Samaroudi, M.,** Weyrich, T. (2020), Fracturing artefacts into 3D printable puzzles to enhance audience engagement with heritage collections. In *Journal on Computing and Cultural Heritage.* 13.1, February 2020

Peer reviewed conference papers

Samaroudi, M., Rodriguez Echavarria, K. (2019), Experiencing art by means of 3D printed replicas: enriching the interpretation of pot Oiseau. In *17th Eurographics Workshop on Graphics and Cultural Heritage,* Sarajevo, Bosnia and Herzegovina, 6-8 November 2019

Samaroudi, M., Rodriguez Echavarria, K. (2019), Learning through experiences: accessible fabricated dioramas for the visually impaired. In *Beck D. et al. (eds) Immersive Learning Research Network. iLRN 2019*. Communications in Computer and Information Science, vol. 1044. Springer, Cham *(best graduate paper award)*

Rodriguez Echavarria, K., & **Samaroudi, M.** (2018), Digital workflow for creating 3D puzzles to engage audiences in the interpretation of archaeological artefacts. In *16th Eurographics Workshop on Graphics and Cultural Heritage,* Vienna, Austria, 12-15 November 2018 *(best paper award)*

Gaugne, R., **Samaroudi, M.,** Nicolas, T., Barreau, J.B., Garnier, L., Rodriguez Echavarria, K., Gouranton, V. (2018), Virtual Reality (VR) interactions with multiple interpretations of archaeological artefacts. In *16th Eurographics Workshop on Graphics and Cultural Heritage,* Vienna, Austria, 12-15 November 2018

Samaroudi, M., Rodriguez Echavarria, K., Song, R., & Evans, R. (2017), The Fabricated Diorama: Tactile Relief and Context-aware Technology for Visually Impaired Audiences. In *15th Eurographics Workshop on Graphics and Cultural Heritage,* Graz, Austria, 27-29 September 2017

Conference presentations

Rodriguez Echavarria, K., **Samaroudi, M.,** 3D experiences to enhance engagement with cultural heritage collections, Develop: Brighton, Insight: Inspiration: Networking, Hilton Brighton Metropole, 9-11 July 2019

Samaroudi, M., Digitally fabricated replicas as means to support cultural heritage interpretation, CEM PhD student conference, Huxley 300, University of Brighton, 11 June 2019

Samaroudi, M., Rodriguez Echavarria, K., Developing and evaluating digitally fabricated replicas as means to support cultural heritage interpretation, SEAHA Conference on Heritage Science, University of Oxford, School of Geography and the Environment, 1-3 April 2019

Rodriguez Echavarria, K., **Samaroudi, M.,** Sa, A., Experiencing heritage through digital fabrication technologies, Digital Research in the Humanities and Arts Conference 2016 (DRHA 2016), University of Brighton, 4-7 September 2016

Other publications

Samaroudi, M., Rodriguez Echavarria, K. (2019), 3D printing is helping museums in repatriation and decolonisation efforts, *The Conversation*, 1 April 2019

Samaroudi, M., Rodriguez Echavarria, K. (2019), How 3D printing is transforming our relationship with cultural heritage, *The Conversation*, 3 December 2019

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Declaration

I declare that the research contained in this thesis, unless otherwise formally indicated within the text, is the original work of the author. The thesis has not been previously submitted to this or any other university for a degree and does not incorporate any material already submitted for a degree.

Signature: Myrsini Samaroudi

Date: 26 July 2021

1 Chapter 1: Introduction

1.1 Context

The subject of the investigation of this research, as suggested by its title, are *digitally fabricated artefacts*, their properties and the way that these work within interpretation frameworks, namely cultural heritage (CH) experiences for different audience groups.

In order to proceed with the description of the study and its components, it is necessary to clarify what the digitally fabricated artefacts are, how experiences are conceived, who constitute the different audiences this thesis often refers to and what kind of organisations museums and other CH institutions are.

Starting from the *digitally fabricated artefact* or *replica*, this can be defined as an object that has been produced by using digital manufacturing[1] technology and refers to/depicts a CH artefact. The production process includes digitally capturing and editing the shape of a heritage object and then using fabrication technology to recreate it (e.g. with a 3D printer).

Coming to *experiences*, it can be argued that these are not just related to the ways that someone subjectively lives; experiences also need an object, activity or situation to create an interaction with. As Krippendorff et al. (2007) suggested *"ex-periences require ex-ternalisation, ex-pression or ex-planations"*. To this purpose, the expression of experiences finds a receptive ground in language and words (how people verbally communicate their experience). Nonetheless, experience is also expressed through visual means, body movements and other forms of expression. Hence, a cultural heritage experience is an interaction between a variety of contextual parameters, including a person, who perceives this interaction and expresses himself/herself in certain ways.

Such person, though, constitutes the member of an *audience*. Generally, the term audiences has a broad meaning, including people who go to a theatre or concert. Audiences might also have a more passive meaning, in terms of people who might go to a museum or event if there

[1] Manufacturing is the process by which materials are converted into finished products usually through mass production. Digital manufacturing involves the use of computer technology during the whole lifecycle of the production of goods including their marketisation (Chryssolouris et al., 2009; Paritala et al., 2017).

is something considered as worthwhile by them. On the other hand, *visitors* actually, physically and socially visit friends, or enter a museum, exhibition or CH setting to take a view (from the Latin verb *visare*, i.e. to view) (Hooper-Greenhill, 1999a; Reeve and Woollard, 2009). For the purposes of this research both words are used interchangeably. Hence, they indicate the wide group of people who might attend an exhibition, take part in a CH event, go to a museum/CH organisation or even enjoy a CH experience in open space. The terms *participants* and *users* also appear often and refer to the audiences or visitors who took part in the research or might potentially be included or affected by it.

Lastly, it should be clarified that *museums* are understood in the broader sense and include all type of CH institutions, collections and events, as defined by ICOM (2007)[2]. ICOM's current definition of museums suggests that *"A museum is a non-profit, permanent institution in the service of society and its development, open to the public, which acquires, conserves, researches,* ***communicates*** *and exhibits the tangible and intangible heritage of humanity and its environment for the purposes of* ***education****,* ***study*** *and* ***enjoyment****"*. The communication aspect with the use of replicas in the CH context is where this research puts emphasis, as described in the following sections.

1.2 Background

In the last decades, *3D technologies*[3] have gained popularity amongst CH professionals as software has also become more accessible. *3D imaging techniques*[4] are now capable of digitally recording more accurately information about the shape, appearance and metrical analysis of moveable and immovable cultural heritage assets. Along with the provision of access to *digital fabrication*[5] and especially *additive manufacturing*[6], curators, conservators

[2] This definition is still valid, despite efforts to establish a new definition in 2019.
[3] 3D technologies refer to the digital acquisition, processing, visualisation and lately physical production (through digital fabrication) of three-dimensional (providing the sense of depth) images or objects.
[4] Imaging techniques include a variety of methods to acquire information about the shape, appearance and internal structure of objects or sites. Often the term encompasses all aspects of digitisation, processing and visualisation of data for a variety of purposes with respect to cultural heritage management.
[5] Digital fabrication is the term to describe the technology behind the production of a tangible 3D model (Mota, 2011; Scopigno et al., 2014). In order to produce a digitally fabricated object -that can either be directly digitally fabricated or the product of a digitally fabricated mould- the process includes the deployment of digital manufacturing in the production pipeline.
[6] Additive manufacturing is the process by which raw materials are used in an additive way to result into finished products. 3D printing is one of the most well-known methods of additive manufacturing.

and other CH stakeholders have become stimulated to deploy these technologies for a variety of processes in managing[7] CH resources. Hence, in recent years the CH domain has witnessed digital fabrication being introduced in exhibition replacements and loans, exhibition planning, tailored packaging for cultural heritage artefacts, restoration, study and research, museum merchandising, creative workshops, interpretative frameworks to support visitors including children and disabled audiences (Balletti et al., 2017; Scopigno et al., 2014, 2015).

At the same time, the interest of the wide public with respect to applications using 3D digital content has risen and coincided with the launch on the market of more affordable portable devices, such as tablets and smartphones, which can perform most of the operations of a personal computer, while supporting their user to access information including 3D representations of sites and artefacts at all times.

People's vivid interest expanded fast from 3D computer visualisations to digital fabrication. This can be witnessed by the introduction of *FAbLAbs*[8] as an outreach project of the *Massachusetts Institute of Technology (MIT)* in 2001 and their worldwide expansion since then. In January 2021, there were 1998 FabLabs registered in the community's international website. They can be found in every continent of the world apart from Antartica (FabLabs, n.d.). The movement behind FabLabs and the public's wish to make their own custom-designed objects without turning to expensive, non-accessible, massive production processes coincided with the DIY movement of the 21st century and the popularity of *Hackerspaces*, as places where people could find support and work towards the idea of democratising processes by employing open hardware and software for all (Mota, 2011).

[7] Cultural heritage management includes the documentation process (content registration, digitisation and research), the protection of heritage assets (storage, security and conservation) and the communication of information (studying, publishing and using cultural material for a variety of dissemination purposes or applications) (Gazi, 2004).

[8] A compound word consisting of the terms fabrication and laboratory. FabLabs have been introduced by the Center for Bits and Atoms of the Massachusetts Institute of Technology (MIT) Media Lab to support their research in 2001. Since then, they have spread worldwide and are controlled by communities. FabLabs are places where people meet and usually enjoy a collaborative approach to *making* things. In FabLabs people can find devices (such as 3D printers), hardware, software and expertise to help them develop the object or product that they have envisaged.

Within the above circumstances, digitally fabricated artefacts have started to appear in museums, CH organisations and events to serve the dissemination of information, support the visiting experience and provide people with the opportunity to "meet" and "feel" culture in alternative ways. Several applications of the technology have been recorded. Some examples include the use of replicas to (more details in section 2.4):

- support visitors in having a more holistic approach to exhibited small scale or large scale artefacts (Guidazzoli et al., 2014; Solima and Tani, 2016).
- invite audiences and artists to participate in creative processes (Bryce, 2015; Mullaney, 2012; Neely and Langer, 2013).
- engage children in educational programmes (AMNH 2013; Neely & Langer 2013; Miles et al. 2015);
- provide interpretative information and physical engagement with a "smart" replica (e.g. with sensors) (Capurro et al., 2015; Marshall et al., 2016);
- encourage people to connect with CH assets by using replicas as input devices for applications (Miles et al., 2015);
- assist visually impaired and blind audiences to experience artefacts by touch and often audio (Neumüller et al. 2014; 3D ArcheoLab 2016; Blakemore 2016; Reichinger, Schröder, et al. 2016; Reichinger, Fuhrmann, et al. 2016; Buonamici et al. 2016);
- support elder audiences with impairment, age-related difficulties, trauma survivors and even young patients, while experiencing the "healing" properties of object handling (Chatterjee et al., 2009; Flowers, 2018; Noble and Chatterjee, 2008; O'Sullivan, 2008; Please Touch, 2016);
- engage families in activities that enhance cultural heritage experiences through collaboration (Miles et al., 2015; Neely and Rozner, 2015);
- involve audience groups as well as professionals in workshops to familiarise with 3D technologies and connect with heritage artefacts (British Museum, 2016; Flowers, 2015; Neely and Rozner, 2015);
- "allow" visitors to enjoy multisensorial experiences of cultural heritage artefacts by producing edible versions of exhibits (Tang and Zhao, 2015);

- make replicas available for people to purchase in museum shops or online (Alberge, 2013; Young, 2017).

By looking at all these examples, the importance of digital fabrication with regards to *interpretation*[9] becomes obvious. The potential of digital fabrication is further strengthened by the possibility to physically experience a digitally fabricated artefact that could have been produced at home, in the classroom or even travel away from a museum as a loan. Under the COVID-19 pandemic circumstances, with movement restrictions and CH settings closed, being able to physically engage with a replica might also acquire a new significance. As recent research demonstrates (Samaroudi et al., 2020), the pandemic has "forced" heritage organisations to find new means to engage their audiences and support other emerging ones (people in self-isolation, vulnerable etc) through a variety of offerings that usually relate to the museums' collections. Yet 3D digital models, which could be further "materialised" into digitally fabricated artefacts, constitute just a small percentage of these offerings. Moreover, and to the best of the author's knowledge, there have not been evidenced any efforts from the heritage sector to provide digitally fabricated replicas as loans to audiences because they cannot access museums due to the pandemic or because they do not have access to online materials; even though there have been some limited efforts to provide physical activity packs (without replicas) to people who do not have access to online materials (Exeter Royal Albert Memorial Museum & Art Gallery, 2020).

Within and beyond these circumstances, the wide range of possibilities of digital fabrication in CH becomes evident if we also consider that researchers, professionals and individuals can exploit all the advantages of being able to manipulate the digital representation of an artefact

[9] Interpretation is the process of meaning-making, making-sense of an experience and generally explaining and interpreting phenomena. In hermeneutics, interpretation is used to describe the construction of meaning by someone or a group of people. Hermeneutics is concerned with the study of texts, but in modern days it also encompasses forms of non-verbal communication (Mantzavinos, 2016). In the cultural heritage sector and especially exhibition design the word interpretation mostly describes the means (e.g. labels, videos) that will provide visitors with the interpretation or explanation of an exhibition or object (Hooper-Greenhill, 1999c). In this thesis, interpretation mostly refers to the user who makes sense of a phenomenon. Nonetheless, it can also pertain to the material which is provided to interpret an object or exhibition in a heritage setting. Therefore, the context of the word in each case will help the reader to identify its meaning, but in most instances the interpretation process is perceived as a constant negotiation within a variety of contextual parameters during a CH experience.

through appropriate software before its production; then produce it in selected materials, colours, weights and so on; while deploying one of many digital fabrication methods (see section 2.2.3) (Scopigno et al., 2014). These are significant features of digital fabrication, creating immeasurable opportunities to customise and enrich the information provided by a tangible digitally fabricated artefact. Such possibilities also demonstrate the potential to represent the inherent pluralistic meaning[10] of objects, while considering different audience needs and circumstances (Cameron, 2010). Nonetheless, such potential inevitably generates a number of questions with regards to the physical nature of the fabricated artefacts and the most appropriate ways to introduce them to audiences in the CH communication domain. This research seeks to investigate this set of questions by adopting a flexible and pragmatic approach that examines the topic of investigation from the *cultural heritage*, *technological* and *making* point of view and their implications in a fast-evolving and topical discourse within the arts and heritage sector.

1.3 Problem statement and knowledge gap

As the creation of digitally fabricated handling objects with different features (size, weight, colour and more) and in many materials becomes a reality, and as gradually more examples of replicas for tactile engagement in heritage settings or events appear, various challenges arise. These challenges highlight our lack of knowledge (Beale et al., 2013; Foster and Jones, 2020; Guidazzoli et al., 2014; Huggett, 2004; Wachowiak and Karas, 2015; Wilson et al., 2017, 2018) in:

- investigating the potential of digitally fabricated artefacts for interpretation and CH communication;
- studying and recognising the actual properties of digitally fabricated artefacts;
- understanding how the properties of digitally fabricated artefacts are sensed by different audiences and their possible implications with respect to interpretation;

[10] In the frame of this research, meaning is constructed as the result of an interaction between objects (and their properties, production and materials), individuals (who carry their own "perceptual burdens") and contexts (e.g. time, space, social composition). Meanings can constantly change with respect to original artefacts and digitally fabricated artefacts.

- understanding the overall performance and contribution of replicas within interpretative scenarios;
- realising what the possible choices are and what decisions need to be made, when designing and introducing a replica within a heritage experiential framework;
- introducing digitally fabricated artefacts in experiences so as to enhance learning, enjoyment and appreciation of CH while avoiding what is described as “technological fetishism”;
- providing guidance on how to effectively plan and design replicas as supportive interpretative means, as well as on how to evaluate their contribution within heritage experiences.

To respond to these challenges, research needs to address the questions around the digitally fabricated artefacts themselves and their dynamics within interpretation frameworks in a systematic way. An in-depth examination of the properties of replicas within realistic interpretative scenarios has not yet been undertaken and it needs to be addressed as it is deeply connected with the narratives around the replica and the heritage object it relates to; it influences the content when designing for an experience with the use of a replica; it aligns -or not- with the perception and expectations that audiences have about digitally fabricated artefacts and the overall expression of the heritage experience (Van der Vaart, 2014).

Therefore, research should attempt to respond to questions about the actual properties of the fabricated artefacts, while evaluating replicas’ contribution in terms of satisfying users and successfully delivering experiences for heritage audiences. Consequently, this project and thesis aim to address questions related -but not restricted- to: the accuracy of digitally fabricated artefacts; the best choices to represent their size, shape, colour and other properties; the media that can complement replicas in interpretation frameworks; the perception of audiences with respect to fabricated artefacts; possible technological gaps that need to be addressed regarding digital fabrication to satisfy audiences’ requirements and more (Van der Vaart, 2014; Zancanaro et al., 2015).

The overall results of the project fill in gaps that exist both in practice and research, by providing an understanding of the digitally fabricated artefacts; by supporting decisions about their production and integration in the CH setting; and by providing guidance on the

investigation of replicas' contribution within CH experiences. Lastly, this study intends to motivate professionals and researchers to explore the potential that digital fabrication technologies offer, in order to reach wider audiences and promote an accessible, inclusive profile for CH institutions.

1.4 Research questions

Taking into consideration the above problem statement and consequently knowledge gap, the need to explore and identify how digitally fabricated artefacts act within interpretative experiences can be addressed by responding to the following research questions (RQ):

RQ1: What are the possible intrinsic and extrinsic properties of digitally fabricated artefacts?

RQ2: In which ways do the properties of digitally fabricated artefacts address the requirements of different audience groups?

RQ3: How do digitally fabricated artefacts work in CH experiences for different audience groups?

RQ4: How can we describe digitally fabricated artefacts in a conceptual model that both documents them and decodes their role within cultural heritage experiences?

Research questions 1 and 2 reflect the *exploratory* nature of the study, as primarily there is a need to explore and define an operational list of properties for the fabricated artefacts and the ways that these might respond to the requirements of different audience groups within interpretative situations or scenarios.

Research questions 3 and 4 pertain to the *explanatory* phase of the study. Here the topic of investigation is the connection between the fabricated artefacts and the audiences in terms of explanation of phenomena. Thus, the contribution of a physical manifestation of an object (the replica) in a CH experience is studied. RQ4 seeks to conceptualise and support the documentation of replicas in order to enhance CH communication processes, such as the incorporation of replicas in real CH interpretative scenarios.

1.5 Research aims and objectives

The aim of this research project is to identify the properties of digitally fabricated artefacts (or replicas) and investigate their dynamics, so as to provide a framework that supports

decisions and improves practices when introducing replicas in cultural heritage experiences for different audience groups.

Therefore, the objectives of the research are:

1. To investigate the intrinsic and extrinsic properties of digitally fabricated artefacts and study issues which are related to their production, materiality, tactile appreciation and overall experience of the object.
2. To identify different cultural heritage audiences, select appropriate representative groups for the purposes of this research and consider their expectations and requirements from digitally fabricated artefacts.
3. To examine the properties of digitally fabricated artefacts with respect to different audience requirements through evaluation within interpretative contexts.
4. To investigate how digitally fabricated artefacts work within cultural heritage experiences and propose ways for their successful integration in real life scenarios.
5. To conceptually describe digitally fabricated artefacts to document the transition from the digital object to its physical manifestation (fabricated product) in ways that can support several CH management processes (e.g. production processes to support documentation) while focusing on communication.

1.6 Contribution to knowledge and practice

This research emphasises the communication aspect of CH experiences. It addresses issues that are related to the deployment of digitally fabricated artefacts as means to physically access CH artefacts and hence support the interpretation process within a heritage experience.

These are the main contributions of the study:

- A theoretical framework serving the study and documentation of replicas by structuring knowledge around them and "decoding" their role in CH experiences.
- A well-rounded set of methods for the systematic and holistic evaluation of replicas within interpretation frameworks.
- Increased understanding about the way that audiences perceive, interact with, and experience digitally fabricated artefacts within interpretative scenarios.

- A comprehensive framework that can be deployed to guide decisions along with a set of recommendations for planning, designing and effectively integrating digitally fabricated artefacts to support audience interpretation.
- A framework and recommendations that can potentially assist efforts for the introduction of standards about the deployment of replicas for communication purposes in the heritage context.
- Revelation of certain computer graphics and digital fabrication drawbacks to address audiences' requirements from replicas.
- A valuable framework/concept that could be deployed to develop intelligent systems to assist curatorial decisions with regards to replicas for CH interpretation.

The above set of contributions cannot, though, be perceived through a single lens, as it belongs to a novel body of knowledge that intersects *cultural heritage* studies, *computing*, *product design* and their related disciplines, as well as the process of *making* by deploying technology. Thus, contributions articulate both the theoretical, analytical and practical point of view as developed within the realm of the research.

1.7 Case studies

To respond to the research questions this thesis investigates digitally fabricated replicas within three real-life cultural heritage experiential frameworks. These case studies respectively target different audience groups as described in section 3.4.9. All case studies were agreed between the researcher and the collaborating organisation, which is the Royal Pavilion and Museums (RPM), Brighton and Hove. The selection of artefacts, audiences and interpretative scenarios was based on criteria related to:

a. the purpose of this research, hence case studies should be meaningful for the investigation;
b. the aims of the collaborating organisation, therefore useful for the RPM's activities and in accordance to its policies and audience development plans;
c. conscious choices with respect to the available means and resources for the research.

Hence, the **first case study**, involves visually impaired audiences interacting with a 3D printed relief and complementary audio smartphone application. The relief represents a portable environmental display (or *diorama*) with a kittiwake from the Booth Museum in Brighton.

The **second case study** targets random adult visitors of the Brighton Museum and Art Gallery (BMAG). The study employs a digitally fabricated pot by Pablo Picasso (Pot Oiseau) from the museum's decorative arts collection.

For the **third case study** a digitally fabricated Iron Age puzzle-pot (Saltdean urn) from the collection of the BMAG has been selected. The target group for this study consists of families with children between the age of six (6) and twelve (12) years old. The puzzle-pot constitutes a permanent hands-on activity incorporated in the New Archaeology Gallery of the BMAG, which has been inaugurated in January 2019.

1.8 Collaboration and support

This research was carried out in collaboration with various institutions that either provided the context to develop and "test" materials and applications or technically supported the research. The RPM have been the collaborating organisation that provided access to its collections and audiences as well as the environment to evaluate the digitally fabricated artefacts. Likewise, the *Blind Veterans* charity in Ovingdean, Brighton and the *Centre for the Education and Rehabilitation for the Blind* in Thessaloniki, Greece also authorised access to evaluate replicas with visually impaired audiences in their premises.

Throughout the research, there has been support from the supervisory team, Dr Karina Rodriguez Echavarria, Dr Roger Evans and Dr Ran Song, members of the *Centre of Secure, Intelligent and Usable Systems* (CSIUS) and the School of Computing, Engineering and Mathematics (CEM) of the University of Brighton (UoB). More specifically, there has been support from the CSIUS and CEM in providing resources for the research, i.e. 3D printing (at the UoB premises), application devices (phones and tablet), imaging equipment and software (3D scanner, lights, tripods, turntables, editing software etc), budget to buy materials, equipment and pay for outsourced services (post-processing materials, artist to paint replicas etc). Particularly important was the support from the *Digitisation Lab* of the UoB. Colleagues from the lab have contributed to technical aspects of the research by providing training to the researcher in 3D scanning and 3D mesh editing, producing semi-automated methods for mesh editing and partitioning (for the Saltdean puzzle-pot) and programming mobile applications (context-aware mobile application for tactile relief and tablet application for Picasso video).

1.9 Chapter organisation

The structure of this document is divided into eight chapters including the present one:

Chapter 2 consists of the literature review which provides the background of this research. The key subjects examined here cover all the different aspects of the production and integration of digitally fabricated artefacts in the CH sector and more specifically in the dissemination of cultural information. The chapter begins with an introduction to digital fabrication technologies and proceeds with a detailed description of replicas and issues around their nature and use in museums and CH institutions with reference to actual examples. The materiality and physicality of replicas are also discussed along with information on visitor studies and different ways to identify audience groups. A detailed discussion around the topic of CH experiences follows, investigating the narratives or stories every experience is built upon. Lastly, the chapter presents related work in the evaluation of CH experiences, with focus on examples where the contribution of replicas is the topic of investigation.

Chapter 3 details the methodology of the study. It describes the research reasoning and approach and explains the rationale behind the selection of the multiple-case study design to address the research questions. The type of evidence and different data collection methods are also discussed here, along with information on the scope of research, the units of analysis, sampling, saturation, triangulation of data, data analysis and further methodological considerations.

Chapter 4 introduces the theoretical framework of the research which investigates the intrinsic and extrinsic properties of the replicas. The chapter explains the difficulties in defining an operational set of properties and proposes the *Replica Experience Framework* (RXF) concept model, which can serve as a map for the documentation, study and evaluation of replicas. The model draws on a multi-disciplinary background, including psychophysics, perception and cognitive psychology, visitor and museum evaluation research, media and product design studies. Based on the RXF model, this chapter also presents information on the function of digitally fabricated artefacts, the production processes which lead to their creation and their sensorial properties.

Chapter 5 presents the first case study of the research. This case study refers to visually impaired audiences interacting with a digitally fabricated relief representing the contents of a Victorian *environmental display* or *diorama* which belongs to the collection of the Booth

Museum in Brighton. The chapter provides information on the initial inspiration for the case study along with further contextual details. It then looks at the design of the digitally fabricated object and the supporting context-aware mobile application. Then, the chapter details the pilot case study, lessons learned from the pilot and the data collection methods that were deployed. Finally, the results of the study are presented, and conclusions follow.

Chapter 6 presents the second case study of the research and reports its results. This case study includes the production of a digitally fabricated artefact, representing an "authentic replica" of the *Pot Oiseau* made by Pablo Picasso, and targets random adult visitors of the BMAG.

Chapter 7 describes the third case study of the research and reports its findings. The third case study involves families (adults with children between 6-12 years old) interacting with a digitally fabricated *Iron Age puzzle-pot urn* from the area of Saltdean. The puzzle-pot constitutes a permanent exhibit of the new Archaeology Gallery at the BMAG, which was launched in January 2019.

Chapter 8 details the across-case examination of the case studies and reflects on the overall findings of the research. The chapter also presents the conclusions of the research, including recommendations for the integration of replicas as interpretative devices within CH experiences, a review of the main theoretical proposition of the research (the *RXF*) along with guidance for its deployment. Finally, the chapter describes how the research questions and objectives have been addressed, highlights the contribution to knowledge and a section about future work suggests further investigations to extend the scope of the research.

2 Chapter 2: Theoretical framework and literature review

2.1 Introduction

The overall goal of this chapter is to analyse the background and the components of an experience with a digitally fabricated artefact. Examples from related literature are presented and discussed so as to contextualise the study and inform the theory, methods and practices which are deployed in the research. In the first instance, *digital fabrication*[11] technologies are presented along with details on the advantages and disadvantages of manufacturing methods. Then, authenticity and the variety of terms to describe digitally fabricated artefacts are discussed. Examples of using replicas to communicate CH information are also included in this chapter in an attempt to gather, record and classify the more representative related work. The materiality aspect of the replicas, with applicable demonstrations in the field of tangible interaction, is another topic analysed here. *Smart replicas*[12] are active examples of digitally fabricated artefacts used as physical interfaces to trigger interaction and engage CH audiences.

Finally, the chapter addresses the topic of experiences, the narratives around them, as well as the different ways to segment CH audiences. The chapter finishes by examining CH evaluation literature with focus on the evaluation of replicas in heritage experiences.

2.2 Digital fabrication

2.2.1 Next industrial revolution

Terms such as the *Next Industrial Revolution* or *Manufacturing Revolution*, suggested by Anderson (2010), Mota (2011) and Berman (2012), have been deeply connected with fabrication technologies and especially *3D printing*, as these are gradually affecting not only the way material goods are produced, but the access people have to manufacturing processes

[11] Digital fabrication is the term which is used to describe the technology behind the production of a tangible 3D model (Mota, 2011; Scopigno et al., 2014). In order to produce a digitally fabricated object -that can either be directly digitally fabricated or the product of a digitally fabricated mould- the process includes the deployment of digital manufacturing in the production pipeline.

[12] Smart replicas are copies of original artefacts that people can interact with and by doing so trigger a reaction or behaviour (e.g. projection of video, audio response) (Marshall et al., 2016).

and the possibilities to adapt products to their needs. Such change is also reflected in the economy environment, where people increasingly expect to relish experiences and products that suit their taste, wants and context (Ratto and Ree, 2012).

Of course, the manufacturing revolution did not happen by chance. It took years for people to develop cheap and easy to use manufacturing tools. Moreover, this change had to occur at the right time, when the economic situation triggered flexible and accessible production practices that were open to customisation (Anderson, 2010; Berman, 2012; Mota, 2011).

Fabricating an object, through a process that takes raw material and transforms it into an object is the closest connection that exists between *graphics software*[13] and the physical manifestation of such product. The story of fabrication, though, is not new. The roots of subtractive manufacturing date back in the 1940s when *Parsons Company of Michigan* created an experimental numerically controlled milling machine. Some years later, in the 1950s, researchers in the MIT created the first computer numerical controlled machine. A decade later, CAD/CAM software was connected to Computer Numerical Control machinery (CNC) and the technology became cheaper with the arrival of minicomputers and lower cost machines. In the 1970s, the technology had already become attractive and was used by many companies (McAllister, 2014).

On the other hand, *rapid prototyping*[14] or *3D printing*, which are the most known terms to describe the additive technique to build an object gradually, made their appearance in the 1980s. In 1981, Dr Kodama (1981) publishes a layer-by-layer approach to create models by using polymers that reacted to light and solidified. In 1984, Charles Hull (1984) invents *stereolithography* (SLA) and in 1986 Carl Deckard and Joe Beaman (1986; 1992), from the University of Texas, invented the first *selective laser sintering* (SLS) machine which works with powder polymers that are joined together with laser. In 1991, Scott Crump of Stratasys Inc. created the first operational *fusion deposition modelling machine* (FDM) for which he had been working for years and had acquired a patent (1979). In almost ten years, the three major

[13] These are computer programmes that allow to manipulate 2D and 3D visualisations. Computer graphics software include programmes to create and edit photos, drawings, 3D models, animations and videos.

[14] Rapid prototyping is a fast, safe, customizable and cost-effective method to create prototypes of products before mass producing them in industry. The automotive industry has been amongst the first adopters of such technology (Paritala et al., 2017).

technologies behind the idea of rapid prototyping (SLA, SLS, FDM) had already been introduced. It took another twenty years in order to explore materials, develop software, add colour to prints and experiment with a variety of applications, from the medical domain to industry, food production and space research (Bensoussan, 2016; Lipson and Kurman, 2013, pp. 7–10).

Even though digital fabrication is not a new player in the manufacturing field, the technology became popular and gained visibility when several initiatives, involving the public in accessible and open manufacturing processes, were launched. All these "making" movements were driven by the unique idea of *democratisation*, which brings people closer to manufacturing processes, tools, technology, software and knowledge to produce objects for a variety of purposes, from artistic expression, to personal and commercial use. As Lipson et al. (2013, p. 50) state: *"The core ethos of the Maker movement is community, creativity, social change, and problem solving".*

Some of the significant actions and innovations that changed the scenery of digital manufacturing in the last decades are (100kGarages, n.d.; FabHub, n.d.; FabLabs, n.d.; Hackerspaces, n.d.; Mota, 2011; Wikipedia, n.d.):

- Online providers of fabrication services: These are companies (Shapeways, Sculpteo, i.materialise and other) offering fabrication services on the Internet. People can upload a 3D model online and have it delivered to their door in a couple of days. Some companies also provide an online marketplace, where people can sell their designs.
- Manufacturing networks: These are places where people can have their design produced by a local shop and tool owner. The designers can choose online a small manufacturer who is willing to undertake the job, adding another source of income to small local businesses. *100kGarages* and *FabHub* are some of these "making" networks.
- Local production places: These constitute initiatives to bring makers, amateurs, designers and technology enthusiasts together in order to collaborate and realise their ideas. *TechShops* (founded in 2006 and closed in 2017) were fabrication studios in the USA, where members had access to a wide range of tools and software. *FabLabs* were also introduced by the MIT in 2001 and today count 1998 registered

labs. Nowadays, FabLabs are controlled by communities and people have free access to equipment, tools and knowledge to fabricate their own products. *Hackerspaces* (introduced in 2006) are community places, where people interested in technology can meet and work on a tech-based project by exchanging ideas and knowledge. There are currently 2403 Hackerspaces around the world.

- Personal printers: In 2004, Andrian Bower from the University of Bath and his student Ed Sells announced the open-source *RepRap* project (2004) to create an affordable printer that could replicate most of its components. Many people joined the effort and contributed with their skills to develop a variety of RepRap kits to build printers which are low-cost. Market opportunities have arisen and companies such as *Makerbot* (2009) emerged to commercialise RepRap printers. Other companies have also started selling low-cost desktop printers such as *Stratasys* (1989) and *3D Systems* (1986) (between 2009-2010).
- Public databases of blueprints: *Thingiverse* (2008) is one of the most well-known free public repositories where people can upload their 3D models or *blueprints*[15] and photos of the fabricated product, while other users can download this model to remix it and create something new. *SketchFab* (2012) is another platform where individuals and organisations publish and share 3D models. SketchFab was founded in 2012, today it contains more than 3 million 3D models. In 2017, there were more than 500 cultural heritage organisations holding an account and publishing their content on its platform (Marchou, 2017). This number is expected to be higher today. SketchFab has also recently launched an effort along with a number of CH organisations to dedicate 3D models to the Public Domain using *Creative Commons Public Domain Dedication (CC0),* which practically allows anyone to copy, edit, re-use 3D heritage models even for commercial use without asking permission (Flynn, 2020).

[15] The term "blueprint" was originally used in architecture and engineering to describe an early drawing, plan for construction. Nowadays it encompasses various sorts of design process and it can be used metaphorically to refer to a plan.

2.2.2 Hype cycle and the future of 3D printing

The feeling of innovation and the excitement of the public for digital fabrication and specifically 3D printing was certainly obvious the years before and after 2010. People thought that they were in the dawn of a novel manufacturing era, when everything was possible and 3D printing could bring all concepts to life (fig. 1).

Figure 1: Front-page of The Economist in February 2011 (2011).

The trend was also reflected on the *Hype Cycle of Emerging Technologies* which is published every year by the IT, research and advisory company *Gartner* to textually and graphically present the maturity of technologies in five stages. These stages are (Gartner Inc., n.d.):

1. *Innovation Trigger*: The phase where a promising technology makes its appearance and some initial concepts are explored by gaining media's attention. Still there is no proof about the adoption or practical implementation of the technology;

2. *Peak of Inflated Expectations*: The second phase is where the expectations rise as some success application stories gain publicity. Some failure stories also appear. A number of companies start working on the field while others not;

3. *Trough of Disillusionment*: The phase of disillusionment happens when some of the efforts to adopt the technology fail and companies abandon the field, unless they can prove success in the specific sector they have been working on;

4. *Slope of Enlightenment*: In phase four, people realise what are the actual benefits of the proposed technology which now seems more mature and applicable. Companies are funded and better products are released on the market;

5. *Plateau of Productivity*: The technology is clearly viable, pays off its providers, is widely adopted and exists in the mainstream market.

The first time that 3D printing, as the most-well known and popular member in the family of fabrication, made its appearance in the *Hype Cycle* was in 2007 (fig. 2) (Fenn et al., 2007). In 2012, 3D printing reached the top of the Cycle as a high-promising technology (fig. 2) (3Ders.org, 2012). In 2015, 3D printing -which was correctly re-named as *Consumer 3D printing* since it does not concern industrial applications- started declining on the Hype Cycle and entered the disillusionment phase (fig. 2). The reason was that individuals and companies began to lose their interest in the technology which seemed less promising than in the past (Stamford, 2015). Another reason could be that the capability to fabricate almost anything does not go along with actual, practical applications in people's everyday lives. Hence, the technology is there, but we really do not know (yet) what to do with it.

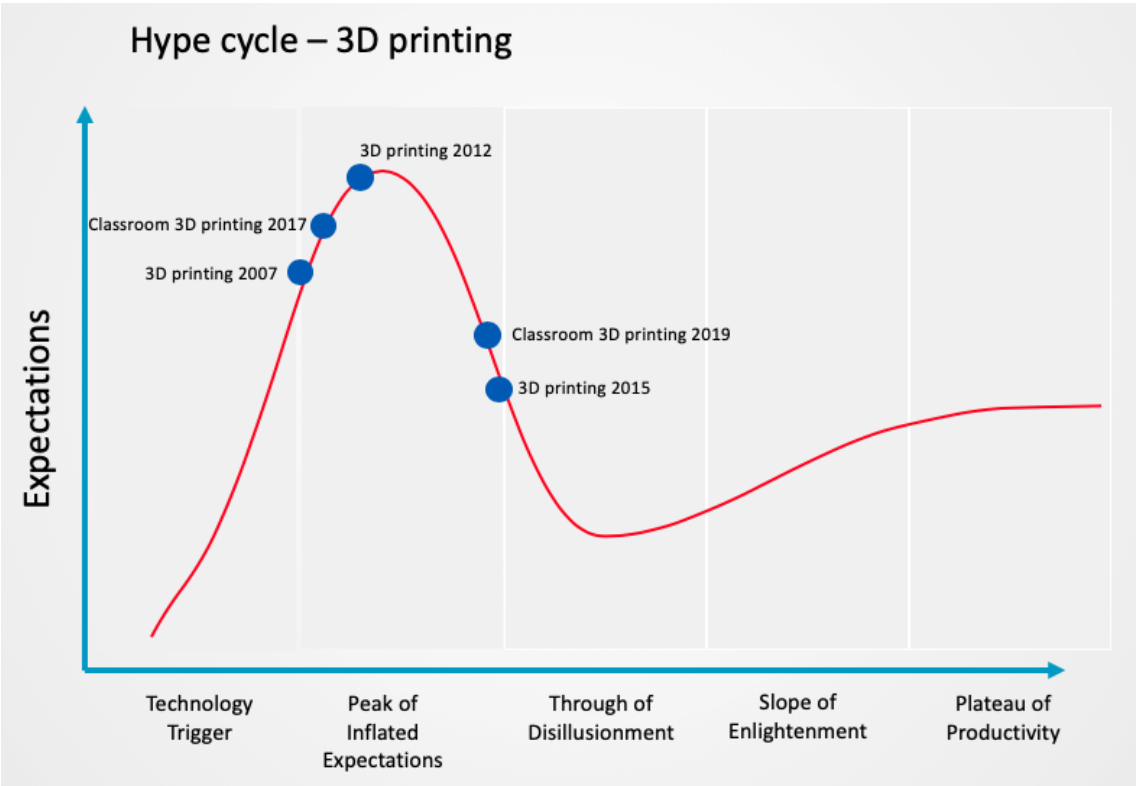


Figure 2: 3D printing on Gartner's Hype Cycle between 2007 and 2019.

In 2017 and 2018, 3D printing is not included in the Hype Cycle, nonetheless 4D printing emerges as an interesting field of research and application, adding the temporal (and thus transformation) element to 3D fabricated objects with a lifespan of more than 10 years to reach plateau (Panetta, 2017, 2018). What is interesting, though, is that in the separate Hype Cycle that Gartner released for 3D printing, *Classroom 3D printing* shows up in the *Peak of Expectations* field in 2017, with a lifespan of five to ten years to reach plateau and find everyday applicability. In 2019, it is located in the phase of *Disillusionment*. This demonstrates that the technology is currently going through a "negotiation" phase about its potential before reaching the next phase, where more mature applicability will be achieved based on the outcome of the negotiation (fig. 2) (3ders.org, 2017; Basiliere and Shanler, 2019). Here, we also have to notice that, even though the term *classroom* can be considered as restrictive, one can only imagine the great potential that 3D printing has with respect to learning. This same learning, with a broad definition of enjoyment, appreciation, knowledge and skill development, is what happens in and out of CH settings, where people can experience digitally fabricated artefacts for the first time.

2.2.3 Subtractive and additive techniques

Digital fabrication technologies can be divided in two groups: the *subtractive* production methods and the *additive* techniques. The former work by removing volume from a block of material to create an object by using *computer numerical control* (CNC) for a cutting machine which is usually a mill, lathe or router. The strength of CNC methods, such as 2.5D CNC Carving and 6-Axis CNC Carving, is that a wide range of materials can be used to produce an object and that they provide a large workspace. Nevertheless, CNC machines might present difficulties in terms of reaching and cutting specific areas of an object (occluded areas), are costly and demand high technical skills to operate.

On the other hand, additive techniques are increasingly gaining popularity, as they become more accessible in terms of cost, ease of use and sustainability (they waste less material in comparison to CNC processes). The additive approach is mostly described as *3D printing* or *rapid prototyping* and it produces an object by gradually building it layer-by-layer. New 3D printing and hybrid techniques constantly emerge. Table 1 presents the most widespread 3D printing techniques (Adami et al., 2015; All3DP, 2019; Balletti et al., 2017; Berman, 2012; Lipson and Kurman, 2013, pp. 68–75; Scopigno et al., 2014; Wachowiak and Karas, 2015).

3D printing techniques	How it works
Fused Deposition Modelling (FDM)	One of the most widespread techniques. It works by heating and extruding raw material through a nozzle. As soon as the soft raw material touches the deposition bed it solidifies. Then another layer is deposited on top of it, gradually building an object. Most consumer printers belong to this type.
Polyjet printing	A hybrid approach. It deploys liquid photopolymers which are sprayed through a head onto a surface and then cured with UV light to solidify. Polyjet printing combines different materials and can print in colour. The available materials are sensitive to light and might prove less durable. Material Jetting (MJ) and Drop on Demand (DOD) techniques work in similar ways.
Laser Engineered Net Shaping (LENS)	LENS works by blowing powder into a laser beam. The powder particles that hit the laser are instantly melted and fused onto the surface of the object which is being built.
Laminated Object Manufacturing (LOM)	LOM printers gradually add pieces of thin material (sheets) which are then cut with a knife or laser into a specific shape. When the first sheet is cut then another one is deposited and cut to form the shape of an object. When the process finishes, the printer presses the layers to create a solid object.
Selective Laser Sintering (SLS)	SLS methods use a powder bed and a high-power laser beam. When the laser touches the powder, the powder melts in the shape of the design guiding the machine. Then another layer of powder is added and the process continues till the object is built. Selective Laser Melting (SLM) and Electronic Beam Melting (EBM) techniques work in similar ways with metal.
Three-Dimensional Printing (3DP)	3DP use the same logic as SLA printers but instead of using laser to melt the powder, they use a type of inkjet head which deposits some kind of adhesive in the form of the desired shape. Then another layer of powder is added. These printers can also jet some drops of coloured ink along with the gluing material and built in colour.
Photopolymerisation or stereolithography (SLA)	SLA works by throwing a beam of light on a container with UV-sensitive photopolymer. As soon as the light touches the liquid material, it solidifies in the form of the predefined shape. Then the tray or container with the liquid lowers or raises slightly and another beam of light hits the liquid. Digital Light Processing (DLP) works also in similar way.

Table 1: 3D printing techniques.

In general, additive manufacturing uses raw materials, such as plastics, super alloys, resins, stainless steel, titanium, polymers and ceramics. The size of the printed object is determined by the surface of the deposition bed and the volume capacity of the 3D printer, thus posing limitations for the dimensions of the final fabricated product.

Whether a subtractive or additive approach is chosen, the main advantages of digital fabrication technologies are: the ease of making one or many one-of-a-kind artefacts; the possibility to create an artefact in one piece (instead of producing several parts which require assembly); the possibility to share designs and outsource manufacturing; the possibility to repeat the process many times based on the digital information of an artefact (Berman, 2012; Mota, 2011). Such advantages can have a beneficial effect in the CH context as described in section 2.5.

Some of the major disadvantages of digital fabrication are related to: the time it takes to create an artefact; the technical knowledge that is demanded by the user to fabricate an artefact; that it is not -yet- possible to produce a finished complex artefact, such as an artefact with electrical functionalities (Berman, 2012; Mota, 2011). Such disadvantages are linked with practical difficulties that CH professionals try to overcome either by outsourcing the production of a replica or by providing technical support when involving audiences in the design and production of digitally fabricated artefacts. Industry and academic research projects are working towards finding solutions to the above described limitations. The constant innovation in the field is obvious if we consider recent developments, such as methods to 3D print in full colour at a nanoscale (Liu et al., 2019); multi-material multi-nozzle 3D printing (Skylar-Scott et al., 2019); and efforts to 3D print flexible transparent electronic circuits (Glier et al., 2019).

2.3 Digitally fabricated artefacts or replicas

2.3.1 Production of replicas

The production of replicas includes all processes that are needed to get from the original design to manufacturing, resulting in a finished product. In simple words, the production pipeline of a digitally fabricated 3D artefact can be structured in two phases:

a. Acquisition and processing of 3D data: This process involves acquisition methods, such as 3D scanning, computed tomography scanning and photogrammetry to “capture” information about the artefact’s shape and appearance. In addition, a 3D digital object can be created by using 3D modelling software. This process will result in a 3D model or 3D mesh which can be visualised and digitally edited to manipulate its shape and other physical behaviours. Nowadays, there is also the option to simply download or purchase a 3D model file through online databases (e.g. thingiverse.com).

b. Digital fabrication: This is the actual manufacturing phase that can be realised in different ways (see 2.2.3). It includes the process of taking a 3D model, producing code for the fabrication machine and physically fabricating it. Then, other post-processing steps need to take place, including joining parts (when needed), removing any supportive material around the object, cleaning it, sanding it and painting it when this is necessary.

The production pipeline might vary in every project and will involve choices in each step of the workflow. More detailed information about the production of digitally fabricated artefacts is presented in 4.5.4.

2.3.2 A term to describe digital fabrication products

A logical question about the product of the above described workflow, though, could be about the right term to describe it. Several words can be found in literature, such as *3D print*, *replica*, *3D replica*, *reproduction*. To select an appropriate term, the perceived qualities of a replica must be identified, so as to differentiate it -if possible- from a reproduction. Such discussion can be extensive. For the purposes of this research a justification for using the term *digitally fabricated artefact* or *replica* is provided.

A *replica* is understood as an object that points to the first/initial object and has a certain degree of faithfulness that could make one think of the original almost immediately. A replica might present the same properties as the original artefact, but has a different spatiotemporal placement, "aura" and other qualities that are related to authenticity. On the other hand, a *reproduction* can simulate the original, but might be a "bad or good" representation and cannot be considered as complete. A *reproduction* could be produced by a process of remodelling, while a replica is produced by copying. Lastly, the word *representation* might suggest a connection with the original object, but one does not necessarily perceive a representation as being the original (Shulan, n.d.).

In the era of fast technological advancement, when the distinction between the original and the other item might become vague, most of these terms could be quickly outdated. For this reason, the use of the actual word *artefact* to complement *digitally fabricated* appears as more appropriate for the research. According to Aristotle's definition of an *artefact*, this could be the product of "the art of making things". An artefact involves intentional agency, but characterising something as an artefact and evaluating it might depend on several conditions

(Hilpinen, 2011). In this case, where the products of work involving a certain degree of intentionality and agency (which might not be limited to human beings and can be direct or indirect) are examined, the artefact is perceived as an object that has been made for some reason. Such a conscious choice indicates a preference in using a low-value term which is related to practical aspects (such as *artisan*, *artifice*) and hence is applied to material with humble, ordinary character (Pearce, 2012). It also reflects an interest in interpreting aspects of the experience of a digitally fabricated artefact whether it is "faithful" or not to the initial object. This experience can only be something authentic as it happens inside us and has the ability to "render" authenticity around us (Hede and Thyne, 2010; Pine and Gilmore, 2007).

Artefacts can also be classified based on their form, manufacturing method, material properties, style, intended use and other processes. The term *digitally fabricated* (to complement artefacts) generally indicates activities which use computer-controlled tools for manufacturing. At the same time, this phrase is broad enough to include products that might originate from future research and could include materials which will be digitally synthesised (Gershenfeld, 2012).

While taking into consideration the above terminology and explanatory information, it must be pointed out that the word *replica* appears to dominate literature around digitally fabricated artefacts. In this thesis, the term *replica* appears alongside the term *digitally fabricated artefact* as an alternative and conventional choice, a common term that corresponds to the related body of knowledge.

2.3.3 Authenticity

The discourse on the *authenticity* of artefacts and generally works of art has long been a vivid topic in cultural heritage studies. In 1935, the German philosopher Walter Benjamin in his famous art critique *The Work of Art in the age of Mechanical Reproduction* (1935) argues that reproducing art has always been a fact. The introduction of mechanical methods to reproduce art, though, is something different, mainly because the original object is confronted not with manual but with technical reproduction. Of course, 3D imaging and digital fabrication had not been invented in the early 20th century, but photography and film had already been introduced bringing revolutionary changes to traditional art. The reason, according to Walter Benjamin, is that mechanical means can capture an aspect of the object, which might not be obvious on the original piece (this happens with 3D imaging as well). Moreover, reproduction

can “transfer” the object to places where the original could never be (this can physically happen with fabrication). Nonetheless, the replicas or reproductions miss some important elements: the unique spatiotemporal existence (aura) of the original artefact; the *“essence of all that is transmissible from its beginning ranging from its substantive duration to its testimony to the history which it has experienced”*; its ritual function, hence its original usage value; and the wholeness of the original artefact. The enjoyment when experiencing a replica, as Benjamin concludes, hides behind politics and the production of sensorial imagery to satisfy the masses (Benjamin, 1935).

Almost a century later, what Walter Benjamin thought of as a decline of art and detachment from traditional principles and values, constitutes a reality. However, there are different approaches and interpretations challenging Benjamin’s ideas. Manually made replicas have long been introduced to serve different purposes in the CH sector. What distinguishes the digitally fabricated replicas from the “traditional” ones is the mechanical or technological mediation that brings several advantages with it (see section 2.5.1 for further details). On the other hand, replicas -regardless of their provenance and context- can still provoke aesthetic appreciation and contribute to holistic experiences for CH audiences. Some authors further discuss about the relation between experiences and authenticity, authenticity ethics and even characterise as fetishists those who insist on it (Koestler, 1955; Sandis, 2016). Insisting on authenticity might even be a tangential matter, when the purpose is a holistic experience. The key decision with respect to authenticity, whether it refers to the original context where an artefact was made, the person who created it, the action of creating it, its original function and all the parameters that could define the “aura” of the authentic object, is to be honest about the exhibition context of the replica and its purpose (Sandis, 2016).

The findings of a research from Hede & Thyne (2017) to identify how people negotiate with the notion of “inauthentic” and the existence of replicas, supports the idea about truth and honesty. Most visitors who were involved in the research did not mind dealing with replicas when they knew what they were. They also appreciated the narrative around replicas, they engaged with the contents of the museum by being free to touch the objects and enjoyed the imaginative process of projecting their own thoughts and feelings on them. As Di Giuseppantonio Di Franco et al. (2015) corroborate through their research, *“we expected that authentic artifacts displayed in a case would trigger “emotions” that 3D copies (virtual and*

real) could not equal. On the contrary our findings show that the conditions Powerwall[16] *and 3D prints were most appreciated, suggesting how our sample of participants are more concerned with experiencing an object through the senses rather than having the original in front of them"*.

Being honest as an institution or researcher, as suggested by the aforementioned researchers, highlights that by no means a given replica intends to substitute the original object or deceive audiences. In fact, both a physical and/or a digital replica can work as complementary interpretative material to support a CH experience. Perceiving replicas in this way might seem difficult for some CH professionals. Some are still reluctant to use 3D digital and physical tools either because they might "take away" some of their authoritative power by "allowing" new engagements and interpretations of heritage to arise (King et al., 2016), or because they cannot understand such potential due to lack of "digital literacy" (Parry et al., 2018). However, providing honest access to replicas agrees with the movement towards a democratised role of CH institutions, which focus on the provision of services to the public while becoming less absolute "authoritative" holders of objects and knowledge.

Ultimately, one should not forget that the heterogeneity of every single experience and the wide spectrum of contextual parameters that define it (sociocultural, physical, personal) might influence the way that authenticity and replicas are perceived (Brida et al., 2012; Hampp and Schwan, 2014). This is something that the current research also takes into account.

2.4 Replicas to communicate CH information

The technological advancements over the last decade along with the attention that 3D printing applications have attracted from the media, have resulted in making digital fabrication a popular topic of research, practice and discussion.

Even though there is still a need to invent ways to bypass several obstacles (related to knowledge, cost, materials, colours and other) before the widespread adoption of fabrication devices in people's everyday lives, the cultural heritage domain has proved to be a valuable

[16] Powerwall is an immersive stereovision system for 3D immersive visualisation.

field to apply digital fabrication. As mentioned before, fabrication technologies have already been implemented in operations that are related to a variety of processes in the CH sector from research, conservation, restoration and exhibition planning to packaging and creative or educational activities (Balletti et al., 2017; Balletti and Ballarin, 2019; Coates, 2019; Morris et al., 2018; Neely and Langer, 2013; Neumüller et al., 2014; Scopigno et al., 2014, 2015).

Some recent examples of using digitally fabricated artefacts to communicate CH to diverse audiences demonstrated interesting results (just to name few, see Guidazzoli et al. 2014; Miles et al. 2015; Damala et al. 2016). Application examples with respect to interpretation, communication and learning can be grouped by different criteria, depending on: the technology that has been deployed to fabricate replicas; the type of object that a replica represents; the audience group that is targeted for an activity using a replica; the type of organisation that incorporated replicas in its communication strategy and other.

The classification that is used in this section employs criteria that are related to the *purpose* (i.e. what is the purpose and goal when using a replica) and *function* (i.e. the task that is assigned to a replica) of digitally fabricated artefacts under the "umbrella" of communication of CH information in the broader sense (education, learning, enjoyment, appreciation, emotions and so on). Certainly, examples might fall under more than one category (e.g. using replicas both for creative purposes and for engaging people experiencing trauma). In such case, the application will be presented under the most obvious category, without eliminating alternative categorisations and overlaps. It should also be mentioned, that an effort has been made to include as many representative examples as possible in this overview. However, in literature, more examples of digitally fabricated artefacts to support interpretation exist and regularly appear. Thus, it would not be possible to mention them all.

In the following paragraphs, several examples of usage of replicas within the context of CH communication are presented.

2.4.1 Replicas to enjoy multisensorial experiences

Replicas can be part of CH exhibitions or events to "facilitate" more holistic experiences of artefacts that are usually out of reach, placed behind glass displays or not physically accessible for a variety of reasons. In this way, replicas become interpretative materials and can be included in an exhibition along with text, photographs, maps and other informative content. Gradually, museums and CH organisations, start to incorporate replicas into their experiential

framework as standalone exhibits (with or without the presence of the original artefact) to support CH interpretation, understanding, appreciation and enjoyment.

Guidazzoli et al. (2014) mention that for the exhibition of the Etruscan heritage at the *Museum of the History of Bologna* a detailed full-size 3D print of the *Sarcophagus of the Spouses* (located in Rome) would be presented in the didactic area of the museum. Hence, people would have the chance to access by sight and touch an iconic artefact of the Etruscan world which is located elsewhere. As the authors argue, having the 3D print along with a variety of digital applications at the centre of the exhibition could lead to better results, satisfying both cultural institutions and the public. Similarly, a 3D printed replica of a marble statue representing a human-lion creature (a medieval type of sphinx) that belongs to the *Museo Civico of Viterbo* was 3D scanned in Italy and 3D printed in the USA in order to form part of the exhibition *Echoes of Egypt: Conjuring the Land of Pharaohs*, which took place in the *Yale Peabody Museum of Natural History* in New Haven (USA) (Urcia et al., 2018).

3D printed reliefs representing illustrations of Santiago Ramón y Cajal, the father of modern neuroscience, have also been included in an exhibition that the *National Institutes of Health* (NIH) in USA organised under the *Intramural Research Program* in 2014. The digitally fabricated reliefs were presented along with Cajal's original illustrations to support the exhibition experience in more holistic tangible ways (National Institutes of Health, 2015). Some of the 3D models that were produced for the exhibition are freely available to download at the NIH 3D print exchange platform (NIH 3D Print Exchange, n.d.).

The *Visual Computing Laboratory* of ISTI-CNR in Italy, in collaboration with the *Opificio delle Pietre Dure* and the *Peggy Guggenheim Collection*, have digitised in 3D Jackson Pollock's *Alchemy* and then produced a physical reproduction of the painting that was exhibited in Venice (Visual Computing Laboratory ISTI-CNR, 2015). Another famous example of the application of digital fabrication to provide multisensorial experiences to audiences is the replica of the prehistoric cave in Lascaux, France. As the original Lascaux cave in France has been closed to the public for decades (due to the deterioration of the wall paintings because of the change in environmental conditions that the human presence brought), several efforts have been made to make the paintings accessible to the public. The latest effort is the *Lascaux IV International Centre for Cave Art*, where 3D printed replicas of the paintings are exhibited along with a 1:1 replica that represents the whole of the original cave. Inside the cave replica,

the light is low and the atmosphere is dark, while sounds are muffled to imitate the environment of the original cave (Lascaux IV International Centre for Cave Art, n.d.).

Amongst the protagonists in the scenery of digital fabrication, the Madrid-based company *Factum Arte* and *Factum Foundation*, have produced several replicas -or *facsimiles* as they prefer to call them- of artworks that have been presented in exhibitions or used for a variety of purposes (conservation, restoration and other). Some of their projects can be found on the company's and foundation's websites. One of their most well-known projects is a replica of Tutankhamun's tomb in the Valley of the Kings in Egypt, which is accessible for the public (Factum Arte, n.d.; Factum Foundation, n.d.).

Finally, one of the latest efforts in the context of multisensorial experiences comes from the *Google Arts and Culture institute*, the non-profit organisation *CyArk* and the American 3D printing manufacturer *Stratasys*, who announced an extended collaboration on the *Open Heritage* project. By printing small-scale versions of cultural heritage sites, the project's team aims to bring important monuments and artefacts around the world to life *"in an effort to get people hooked and excited about seeing pieces in a museum or research context"* (Google Arts & Culture, n.d.; Librett, 2019).

2.4.2 Replicas to artistically remix

An interesting idea to enhance appreciation and connection with CH artefacts involves 3D imaging, 3D remixing and 3D printing of hybrid collection objects, which usually represent: two or more museum objects synthesised to create a new figure; a 3D model of an object combined with other imaginary additions; a "tweaked" model of a digitised museum object. The new hybrid objects reflect the expression and creativity of the artists (or audiences) and can be considered as physical manifestations of the ideas, thoughts, relations that people build by experiencing CH objects. Such activities constitute rather innovative applications of 3D technologies in CH communication, as people are not simply "allowed" to access information but are motivated to "play" with it in creative ways. Showcasing remixed examples and advertising them goes one step further into the idea of *democratisation* of CH as organisations might be willing to detach gradually from their authoritative profile and give space to other voices. This is also demonstrated by recent efforts to launch public domain dedication for 3D CH assets, such as the one announced by Sketchfab and various CH organisations (Flynn, 2020).

A tomb figurine from the Eastern Han dynasty (A.D. 25–220) and an architectural brick with ogre mask from the Tang dynasty (A.D. 618–907) at the *Art Institute of Chicago* were mixed by the artist, Tom Burtonwood, who created the *Ogre puppy* in 2012. (Neely and Langer, 2013). The same institution (Neely and Rozner, 2015) ran the programme *Object: Remixed, Reconfigured* in 2014 for tweens. The participants chose artefacts from the museum's galleries and remixed them to create their own version of artworks.

In 2012, the *Metropolitan Museum of Art* in New York invited digital artists to capture and print their 3D models during a *Hackathon* two-day event. Artists created remixed objects from the museum's collections and uploaded them online (Mullaney, 2012; Neely and Langer, 2013). One of the most interesting results of this experimentation was a 3D mashup of the statues of Leda and the Swan (by Jacques Sarazin) and Marsyas (by Balthasar Permoser). The new hybrid object was named *Leda and the Marsyas* and was designed by Jonathan Monaghan who stated that the experience *"illustrates the mutability of 3D models and the ease with which users can create new content out of what already exists"* (Undeen, 2013). Another example, the iconic *Portus Head*, excavated by the University of Southampton in 2012 at the ancient port of Rome, has been transformed as part of an artistic process and is exhibited at the University as a symbol of the work of institutional partners during the project (Beale et al., 2013).

Finally, a different activity that involved physically remixing 3D printed parts of Rodin's sculptures took place at the *Portland Art Museum* during the exhibition *Rodin: The human experience*. At a separate space in the exhibition, 3D printed parts from Rodin's sculptures were made available to visitors. The parts had magnets to help visitors assemble their own versions of Rodin's work (and share on social media). Apart from the creative aspect of the process, the museum officers discuss the educational benefits from the involvement of the audience in such activities (Noto, 2017).

2.4.3 Replicas to enhance learning and education

In accordance with the *constructivist* learning approach[17], suggesting that children engage, understand, create meanings and learn actively when interacting with objects, CH organisations have deployed replicas in children, family and school activities. Hence, using replicas in the field of educational programmes constituted some of the first applications of fabrication technology in the CH context. The examples of such deployments are many, so only few of them are mentioned here to give an idea of the variety of existing applications.

A megalithic stone from the Welsh island of Anglesey was segmented into pieces to create a puzzle, that children could assemble using a central pillar, for the outreach activities of the *Heritage Together* project in the UK. The activity has proved to be engaging for older children but not very successful for the younger ones (for whom it was initially designed) (Miles et al., 2015). The reason could be that people still do not know what features to incorporate into replicas (or what properties to manipulate) and then how to successfully introduce them in CH activities for specific audiences.

In 2013, the *American Museum of Natural History* launched an educational programme for high school children. Students were asked to digitise, process and 3D print dinosaur bones and then assemble the skeleton of a dinosaur in order to identify the species. The activity engaged children with palaeontology, introduced them to comparative anatomy and, most importantly, worked as a critical thinking and practical skill acquisition framework which is rich and fundamentally beneficial for learning (AMNH, 2013).

[17] Constructivist learning theories argue that in addition to using information which reaches our organs and senses, humans also make use of previous beliefs, expectations and motivations in a constant negotiation between prior experiences and new realities to form knowledge (Coren et al., 1999; Falk and Dierking, 1992; Jensen, 1999).

Figure 3: Replicas of stone tools, hand-axes with the supporting material as they came out of the 3D printer and pots. All printed for the Stone Age educational sessions at the Hove Museum.

Another interesting project comes from the collaboration of the UoB with the educational department of the RPM. Researchers from the Digitisation Lab of the CSIUS 3D scanned and 3D printed replicas of objects from the archaeological collection of the Brighton Museum. Replicas of pots, hand-axes and stone tools where given to primary school children participating in the *Stone Age* sessions at the Hove Museum (fig. 3). Children were invited to associate the fabricated artefacts to fictional characters (a toolmaker, farmer, potter etc.) from the Mesolithic and Neolithic periods. They were also asked to exchange each character's belongings (comprising of wooden, felt, leather, plastic objects and the 3D prints) with the other characters' possessions, in order to imitate and understand the trading activities taking place in Neolithic times at the causewayed enclosure of the Whitehawk Hill in Brighton. The hands-on activities and especially the trading activity with the use of replicas proved to be engaging for the children. The material, colours, weight and other properties of the physical objects generated discussions around them, enhancing children's understanding about the function of objects as well as the technology used for their production.

2.4.4 Replicas to experience the physical and the digital world

This is one of the latest "trends" in the field of CH communication with the use of replicas. It is considered as a very active field of research with many parties exploring ideas that combine replicas with alternative digital content presentations, embedding hardware into physical objects that behave in intelligent ways.

Deploying *smart replicas* in exhibitions and events is described as state-of-the-art in the CH context. Smart replicas are digitally fabricated artefacts that work as tangible interfaces, so that people can interact with them and by doing this trigger some response in the form of a

reaction or behaviour (e.g. the projection of an animation, an audio response and other) (Marshall et al., 2016). Integrating smart replicas in the CH environment is a rather innovative approach, attempting to unite the physical and the digital part (often described as "phygital") into one experiential framework. A recent EU funded project, *MeSch* (2017; Petrelli et al., 2014), employed replicas and other copies of objects to provide further layers of interpretative information and physical engagement with artefacts, complementing the visiting experience and interpretation in exhibitions, such as the *Atlantic Wall: War in the city of peace* in Hague and the *Feint - The Illusion of Movement in Ancient Greek Art* at the *Allard Pierson Museum* in Amsterdam (Marshall et al., 2016; Waag Society, 2015).

Another relevant example is the *Virtex* system. For this project, researchers placed touch sensors inside two replicas (statue of *Augustus of Prima Porta* and the *Ara Pacis* monument in Rome) for the exhibition *Keys to Rome* at the *Allard Pierson Museum*. When visitors touched the tiny buttons that were integrated into specific points of the replicas, relevant storytelling content was projected on a screen, complementing the tactile experience of the replica (Capurro et al., 2015).

Replicas can also trigger interaction without having any kind of hardware (sensors, near field communication (NFC) tags or other) embedded into their physical form. Thus, they can be used as input devices, such as a computer mouse or joystick, in order to activate some content on an output or input/output device. Researchers deployed such a hybrid solution for the outreach activities of the *Heritage together* project in the UK. 3D printed miniatures of megalithic monuments from Wales (created through crowdsourced photogrammetry) were placed on a multitouch table. The replicas acted as fingers touching different points on the screen and triggered relevant interpretative information. The application received positive feedback and it was successful especially with children. Nonetheless, the use of the replicas was not always clear, as people did not know whether this was a game activity and in some cases adults were not confident when using the touch table (Miles et al., 2015).

Replicas have also been used in augmented reality (AR) applications. Some interesting examples come from Maaike Roozenburg's studio in the Netherlands (Studio Maaike Roozenburg, 2017). The designer has collaborated with academics from several universities and the curator Abdelkader Benali for the exhibition *I cook therefore I am*, which was presented at the *Wereldmuseum* of Rotterdam. Video mapping technology was used on the

surface of three scaled-up replicas of cuneiform tablets to present information about the cooking recipes that are described on them, witnessing some of the oldest culinary data in the world (Studio Maaike Roozenburg, 2017). Another application from the same studio uses physical ceramic replicas, which are "enriched" with material from an AR mobile application. The user can download the app and point his/her mobile phone to an open foldable cardboard that works as a marker. Then, a timeline appears providing textual, visual and sound information about the replica which is placed at the centre of the box (Studio Maaike Roozenburg and LikeFriends Creative Agency, 2016).

2.4.5 Replicas to assist visually impaired people to experience artefacts

In recent years, there have been a number of projects that focus on the provision of *multisensorial experiences*[18], which combine tactile explorations with explanatory auditive information from a device, for visually impaired audiences. One of the early examples was a 3D printed figurine representing the artist Rita Furrer covered with cloth, made at the Vienna University of Technology in 2010. The figurine was then used by blind visitors during a museum "touch tour" (Neumüller et al., 2014). Also, a total of four paintings coming from the *Kunsthistorisches Museum* in Vienna were produced and 3D printed in the form of "layered-diagrams" and "textured reliefs" by the Austrian *VRVis* research centre. These reliefs were tested with visually impaired users with the support of trained guides. Users reported that they had a clearer understanding of the composition of paintings and depth details when exploring the reliefs, which added another layer of perception with respect to visual arts (Reichinger et al., 2011).

A series of guided tours called *Hands On!* took place at the *Art Institute of Chicago* in 2014 to enhance the visiting experience for people with low vision. Four artefacts from each gallery were fabricated and given to people to touch, while listening to descriptions by the museum staff, along with other relevant material, such as music and sounds produced by the objects themselves (bell, whistle). One of the findings of the evaluation of the programme

[18] Experiences that people live with more than one of their senses. This could include the sense of touch, vision, smell, taste and hearing.

demonstrated that visually impaired people developed a deeply emotional relationship with the objects which -in some cases- had an “awakening” power (Neely and Rozner, 2015).

Several projects make also use of digitally fabricated objects and multimedia content to support non-guided interpretation for visually impaired users. For instance, the *Orasis* project deploys Arduino boards, touch sensors and a mobile app to enhance access to museums for blind users (Anagnostakis and Antoniou, 2016). The preliminary evaluation of this system showed that participants valued the application and would like to deploy it in museum environments. Though, controlling the descriptive audio through gestures on a mobile phone while exploring the replica proved easier for totally blind users than for the partially sighted. A similar project at the *National Etruscan Museum of Marzabotto* (Italy) utilised 3D replicas, NFC technology and QR codes (Quick Response Code) along with a mobile app to allow visitors to enjoy audio descriptions about the artefacts (3D ArcheoLab, 2016). The visually impaired people who participated in the project reported that they were able to discover more about history and their homeland by deploying touch. Another project, realised by researchers in Austria and the UK, deployed touch sensors on a “digital touch replica” of an Egyptian cat sarcophagus to trigger audio descriptions. People expressed positive comments about the fact that the replica was printed in wood composite, resembling the original material of the artefact. However, they found difficult to explore the object freely, as the audio was always triggering when touching the cat (Reichinger, Schröder, et al., 2016).

Digitally fabricated reliefs have also been introduced to communicate relatively “flat” information (or to “translate” into flat information), such as architectural facades, photos and paintings. Artworks in the form of 3D printed reliefs (along with full 3D representations) were produced for the *Bendigo Art Gallery* in Australia in order to create a “value-sensitive” methodology providing access to artefacts to visually impaired users (Butler et al., 2019; Holloway et al., 2019). The Tooteko app case study (D’Agnano et al., 2015) deployed NFC technology (ring and tags) to provide audio descriptions of a 15th century church facade in Italy. A USA-based company named *3DPhotoworks* produced coloured tactile prints of paintings and photos. Their prints for the *Sight Unseen* exhibition at the *Canadian Museum for Human Rights* embedded touch sensors to trigger audio descriptions. Comments from the people who interacted with the reliefs were positive. 3DPhotoworks’ director has claimed that the provision of such assets is a step towards independent, unaided exploration, which

is a basic human right (3DPhotoWorks, n.d., n.d.). In addition, the *Touch the Prado* exhibition in Madrid featured coloured replicas of famous paintings along with audio descriptions (Hewitt, 2015). These replicas were coloured with a process that is not exactly known but deployed other methods for the addition of colour rather than 3D printing.

The *Out Loud* exhibition at the *Andy Warhol Museum* in Pittsburgh (USA) showcased tactile representations of artwork from Warhol and supported the tactile experience with audio descriptions using location-aware technology and a dedicated mobile app. Blind people collaborated with the museum and the IT company as consultants in order to provide useful ideas and feedback for the design of the audio application (Blakemore, 2016; Morelli, 2016). A system using a camera and gesture recognition (on and off the object) to provide audio descriptions for Klimt's *Kiss* tactile painting has also been produced by the *VRVis* research centre in collaboration with the University of Vienna. Users who tested the object and application gave positive feedback, nonetheless some problems with the audio system occurred either because of wrong hand/gesture positioning or because of the limitations in hand/gesture recognition by the camera system (Reichinger, Fuhrmann, et al., 2016a, 2016b). Similar applications have also been deployed within the *ARCHES* (Arches, 2019) EU funded project, in order to *"create more inclusive cultural environments for people with differences and difficulties associated with perception, memory, cognition and communication".* Finally, another relevant system developed by Buonamici et al. (2016) used a Microsoft Kinect depth-sensing scanner to detect users' finger position with respect to a bas-relief and provide audio information. The application seems promising, yet it presented some problems with the hand tracking system and identification of touch.

2.4.6 Replicas to enhance social interaction, remembrance and comfort

Digitally fabricated artefacts have been produced and employed in programmes especially designed for older audiences having an impairment (such as visual impairment); for people facing age-related difficulties, such as dementia; for trauma survivors; or audiences that are receiving treatment in health facilities.

The *Please Touch* project and related *Stories in Process* exhibition was funded and supported by the Sheffield Hallam University (Knowlson, 2016). The curators and researchers of the project presented replicas of objects from the Social History Collection of *Museums Sheffield* to older visually impaired people from the *Sheffield Royal Society for the Blind*. The tactile

exploration of the objects and related audio, motivated participants to narrate stories from their childhood and difficult periods such as the Second World War. A series of *reminiscence*[19] workshops worked as an "engagement vehicle" for people, who became associated with the objects and explored personal and community narratives with the rest of the participants.

Figure 4: The original artefact on the left and its replica as painted by the group on the right.

A different project at the BMAG in 2017 explored the creative use of a replica of a ceramic bulldog, which was significant to a member of a group consisting of people experiencing some kind of trauma or mental health issue (Collectingbulldogs.com, 2017). These people were involved in a series of art workshops and also attended a session about 3D printing, where miniatures of the selected object were printed live. Moreover, a full-size replica of the selected artefact was provided to them by the author of this thesis and was painted later by several members of the group in their chosen colours (giving it David Bowie's eyes as they said) (fig. 4). The mentors of the group had positive comments about the experience, emphasising how the members of the group creatively engaged with the activity.

Lastly, an interesting project that intersects creativity, remixing and comfort was a collaboration between the Victoria and Albert Museum (V&A), the *GOSH Arts programme* at *Great Ormond Street* and other hospitals. Officers from the museum visited young patients in

[19] Reminiscence is the action to recall memories and life experiences. Reminiscence can have the form of a textual or verbal narrative, the form of a painting, of an object and other expressive means.

hospital wards and asked them to remix 3D models of museum artefacts in order to create their desired models. Then the designs were 3D printed and presented to the patients. The activities generated various discussions around the objects, as well as patients' desires and ideas in an environment where they often experience isolation and distancing from creative processes (Flowers, 2018).

All the above described examples present common elements of social interaction, collaboration, memory retrieval, sharing and object handling or creatively remixing. Such activities and their implications have demonstrated their "healing" properties and benefits for people facing several conditions before (Chatterjee et al., 2009; Noble and Chatterjee, 2008; O'Sullivan, 2008).

2.4.7 Replicas to explore through workshops and creative sessions

Recently, museums and CH organisations launched events and series of workshops, usually addressed to families, teenagers, young adults and professionals, in order to familiarise audiences with 3D technologies and engage them in collaborative creative activities. During several days/weeks or one-off sessions, people can get involved in 3D scanning, designing, editing and 3D printing models representing museum artefacts, their own artwork inspired by museum objects or just their own designs. The *Art Institute of Chicago* chose 3D printing amongst the processes that teenagers explored during the *Teen Lab* workshops. The same institute organised in 2014 workshops for teachers to introduce them to the 3D printing production pipeline. Teachers used the objects of the museum as inspiration for artwork. Another family event, invited children and adults to sit on a turn-platform, posing in the style of a sculpture from the galleries of the museum. A facilitator digitised families, while other people observed 3D printers working (amongst other 3D oriented events). All workshops have proved valuable opportunities to trigger people's interest around technology and art, and discuss about perception and reproduction of artwork (Neely and Rozner, 2015).

Some more examples include a *Scanathon*, a 3D scanning skills workshop and a 3D printing workshop for families at the *British Museum* as well as a 3D printed jewellery workshop for teenagers launched by the *V&A* (British Museum, 2014, 2016; Bryce, 2015; Flowers, 2015). The *Museum of Design* in Atlanta (USA) organised 3D printing workshops for adults and also delivered private 3D printing lessons to those who were interested in the technology (Museum of Design Atlanta, n.d.). The *Museum of Life and Science* in Durham (USA) delivered,

within the *Tinker Tech* family workshops, sessions about the basics of 3D computer design and 3D printing (Museum of Life and Science, 2016); the *Design Museum* in London offered 3D design and 3D printing events to families (Design Museum, 2017); and the *Metropolitan Museum of Art (Met)* in collaboration with the *Ultimaker North America's Community* team offered the *Met Set* series lessons to bring the museum artefacts and 3D printing into the classroom (Griffin and Arum, 2019).

Figure 5: 3D printing at the BMAG.

At a local level, the BMAG included 3D printing sessions in the "Dig it! Family Archaeology Day" in 2016, 2017 and 2019. Adults and children had the chance to touch various 3D printed replicas coming from the collections of the museum, watch a portable 3D printer in action and get involved in creative craft activities (fig. 5). During these sessions, people asked several questions about the technology, the materials, the colours and post-processing of the replicas. In this instance, technology worked as an engagement mechanism to examine objects and gain a better understanding about the appearance, feeling, function and use of both the original and the replica artefact.

2.4.8 Replicas to enjoy focusing on smell and taste

Enjoying replicas through multisensorial experiences is an active field of research and practice. The multisensorial spectrum, though, often neglects smell and especially taste, because they are perceived as rather "irrelevant" senses. Nonetheless, smell is one of the strongest mechanisms for memory retrieval and active engagement. Similarly, taste can provoke thinking or inspiration and constitutes an alternative method to connect with objects

and their stories. People at the *MediaLab* of the *Met* in New York created edible replicas of museum artefacts to allow visitors to enjoy multisensorial experiences of cultural heritage, while emphasising on smell and taste (due to the edible materials used). They also produced a kit for visitors to make their own edible artefacts (Tang and Zhao, 2015). These approaches might appear unusual, but they demonstrate innovative ways to engage audiences with collections through important yet forgotten senses.

2.4.9 Replicas to offer and to take home

Digitally fabricated artefacts have also made their appearance in museum shops for visitors to purchase. The *Van Gogh Museum* in Amsterdam was one of the pioneers when starting selling replicas that were produced in collaboration with *Fujifilm* in 2013 for the considerable price of £22.000 (Alberge, 2013). The *British Museum* also started selling replicas of objects from its collections after collaborating with the company *ThinkSee3D* (British Museum, 2017; Young, 2017). The *Natural History Museum* in London sells replicas of natural specimens which were also produced through a moulding process (Natural History Museum, n.d.). In Italy, researchers from the *VisitLab* of the *Cineca Interuniversity Consortium* have collaborated with the *National Etruscan Museum of Villa Giulia*, to create 3D printed miniature versions of *Ati* (a fictional Roman character) and the famous *Sarcophagus of the Spouses*, a masterpiece of Etruscan art located at the Villa Giulia, to sell at the museum store (Guidazzoli et al., 2014). By purchasing a replica, people can take artefacts home and keep them close to them. They can also offer them as gifts to friends and family. In these ways, people establish connections with artefacts, which might have a significance further than that of a mere souvenir purchased from a museum shop.

2.4.10 Replicas to repatriate CH artefacts

Producing replicas for repatriation and decolonisation is a topical and open matter of discussion. When deploying digitally fabricated artefacts for repatriation purposes, collaboration of the interested parties is essential to overcome difficulties related to copyright, cost, ethics and the crucial question of who keeps the original.

The *Smithsonian's National Museum of Natural History* has worked with the Tlingit native community of southeast Alaska to return objects which are considered sacred, of special importance or related to funerary practices of the community. Such decisions fall under specific law regulations; mainly, the *National Museum of the American Indian Act* (1989) and

its later amendments that support the repatriation of important artefacts satisfying certain criteria. In this case, some of the objects that were returned to the Tlingit communities were digitised in 3D and a significant Killer Whale clan crest hat was digitally fabricated and accurately replicated to be kept at the possession of the museum (Hollinger et al., 2013). Another case of repatriation within the same country is that of *the Sámi Museum Siida* in Inari, Finland. Seventy (70) artefacts, coming from the Arctic Sámi communities were recently repatriated from the *Hämeenlinna City Museum* and the *Museum Centre Vapriikkiin* in Tampere, Finland to the Sámi Museum Siida. Thousands more artefacts of the Sámi culture are also expected to be repatriated to the Siida Museum in the following years. In this project, researchers made use of photogrammetry to digitally capture several repatriated artefacts and then offer their 3D models to the local artisans' community to facilitate copying designs and education. Access to the models is under discussion with the local communities to see whether the 3D models can only be viewed online or downloaded too (something that could facilitate printing) (Magnani et al., 2018).

Lastly, a controversial example of repatriation is the project that artists Nora Al-Badri and Jan Nikolai Nelles undertook secretly at the *Neues Museum* in Berlin. The artists claimed that they scanned the bust of Nefertiti at the museum using a Microsoft Xbox 360 Kinect scanner. Then, they released the 3D data online as a torrent during the *Chaos Communication Congress*. A 3D replica of Nefertiti's bust was also created and exhibited at the *Something Else Off Biennale* in Cairo and later it would be presented at the American University of Cairo. The artists claimed that their intention was to return Nefertiti to her homeland and criticised the colonialist practices of Western museums (Nelles and Al-Bdri, 2016; Voone, 2016). However, there is controversy around the project and especially the fact that such a detailed model could never be the result of the mode of acquisition suggested by the artists. Therefore, there are specialists saying that the 3D model is probably the result of hack on the museum's servers or internal leak from the museum staff (Docherty, 2016; Kahl, 2016).

2.5 Materiality, appreciation and meaningful experiences

2.5.1 The "material turn"

One of the most important contributions of digitally fabricated artefacts in communicating CH information is their own material or physical aspect. Materiality is recognised as a substantial component in the cognition process and thus in complementing a personally

meaningful experience that enhances audiences' appreciation of cultural values (Dudley, 2010). Materiality is also recognised by some authors as holding a power *per se*, which can be transformative at a personal, emotional and sensory level by revealing a "wonder" in front of the visitor, even before enhancing subsequent learning and appreciation (Dudley, 2012).

Therefore, replicas can serve as "engagement vehicles" through tactile and multisensorial activities that add value to the CH experience. From the visitor's perspective, viewing an object, feeling its weight and examining its shape through hands-on and sensorial interactions are processes that support meaning-making and interpretation. From the CH sector's perspective, such provision or facilitation reflects the "material turn" of museums and art education. Thus, replicas have the potential to change the landscape of CH experiences in ways that have never been possible before, due to the sensitive or fragile nature of collections and limitations regarding the actual access to manufacturing processes (Beale et al., 2013; Lipson and Kurman, 2013, p. 168; Neumüller et al., 2014; Zancanaro et al., 2015).

This "material turn" brings people's attention back to the real world. Hence, there are some extra advantages and innovative elements, when a replica is deployed instead or along with other physical interpretative media (such as videos, images, leaflets etc.) or "traditionally made" replicas. These are:

- the possibility to have a more "accurate"[20] and "non-obtrusive" replica of an original artefact since it is not the result of handmade (and potentially harmful) production;
- the possibility to produce many replicas regardless of spatiotemporal boundaries, as the replicability relies primarily on the existence and sharing of a digital file;
- the capability to feel the heritage object outside of a protective case or display;
- the potential to engage different groups of visitors at a physical level;

[20] The term "accurate" is problematic and can be analysed in many ways. Accuracy might take into consideration physical aspects of the object or spatiotemporal (aura) phenomena. Currently, there is no consensus as for the "accuracy" of the digitally fabricated artefacts, because this definition should include the "accuracy" of the acquisition process, the "accuracy" of the model editing process and the "accuracy" of the actual fabrication, for which clear criteria do not exist. Here the term is mostly used to describe something which appears as being faithful to the original artefact.

- the possibility to involve visitors in the whole production pipeline of replicas;
- the possibility to customise digitally fabricated artefacts, segment them, enhance some of their features or even produce new objects -that will use the initial form as inspiration- to satisfy users' requirements;
- the exploration of using replicas as devices that will generate digital content within experiences by investigating the co-existence of digital and physical.

All these elements could outline what can be defined as a novel, "holistic" way to experience CH artefacts. Holistic experiences are not only important but vital for those that cannot fully appreciate the original artefacts, such as visually impaired audiences, children, people with learning difficulties and the elderly. In the case of children, digital fabrication products can be considered as valuable stimuli for deep learning, as new materials and objects "blend" with previous experiences and positively complicate knowledge (Cabral and Justice, 2013). For visually impaired people, whose exploration and knowledge of things is largely dependent on touch, replicas can open a new window to understand the world. When this exploration is accompanied by other sensorial material, it might even become an emotional experience. The possibilities are endless if we consider how digitally fabricated artefacts and their supporting interpretative material can be adapted to benefit all those favouring tactile experiences or simply different audience groups (D'Agnano et al., 2015; Neely and Rozner, 2015).

Key to understanding how replicas work in complementing and adding value to meaningful CH experiences is to "decode" their role in the creation of meaning. For this project, the discourse that explores experiences through the interaction or negotiation between artefacts, individuals and the context of the visit will be deployed (see Chapter 4). Hence, real-time engagements with a material thing (the replica) and its physicality are studied through a variety of case studies.

2.5.2 The power of touch

Touch constitutes one of the most important senses of human organisms. The exceptional nature of touch has long been studied and debated amongst philosophers, theorists and researchers examining its nature, mechanisms, power and potential.

Aristotle, starting from an investigation of biological ideas, studied the nature of senses in his works *Sense and Sensibilia* and *On the Soul*, and classified them reflecting their connection to pleasure as described in his *Ethics*. In Aristotle's analysis, sight is the superior sense and touch

is classified as an exceptional sense yet placed at the bottom base of his classification. This is due to touch's fundamental importance for survival, its "primitive character" and its connection to "carnal" pleasures. Moreover, touch does not correspond to a distinct organ, like the eyes and ears that are directly related to sight and hearing. Instead, our flesh works as the medium of touch, attributing an internal character to this sense which is ultimately connected with our heart (Paterson, 2007a, pp. 15–17). In addition, touch holds a verification aspect, working as the most reliable witness of the complexity of the world around us and as an active gesture of communication and empathy for others (Paterson, 2007b, pp. 1–2).

Even though studied at a great extent, touch has remained neglected in the industrialised Western civilisation, basically because of the emphasis on vision at a pragmatic and theoretical level. Touch has also been prohibited in most museums and CH institutions -up to an extent justifiably- for preservation and conservation purposes. In the 18th century, during the first steps of museums, privileged visitors were allowed to touch objects in European museums in order to fully appreciate them. In the 19th century, when museums opened up to "low class" visitors, more restrictions with respect to touch were introduced as people's (working) hands were thought to contaminate the objects. Gradually, touch almost became banned from the museum scenery as conservation and security reasons impose (fig. 6). Today, even when it is forbidden, many museum visitors tend to touch exhibited artefacts in an effort to verify their visual impression with tactile cues. These people seem to enjoy the feeling of exploring the surface of an object or connecting with it in a deeper, more intimate sense (Candlin, 2008; MacDonald, 2007).

Figure 6: Signs at the entrance kiosk of the British Museum (left) and at Tate Modern's exhibition rooms (right). Photos taken by the author.

Touch and more precisely *haptics*, as the constant collaboration between *kinaesthesia* and touch, also interact with other senses in order to support interpretation in the CH context (more details on stimuli, haptics and senses are presented in 4.5.3). Tactile experiences have the capability to elicit emotional expressions. Furthermore, they facilitate object recognition and information storage, in accordance with the constructivist approach. On a more radical basis, tactile explorations can form part of holistic multisensorial experiences, where meaning-making can be fluid, altered and constructed by active visitors as *"the 'original' coexists with the 'copy' as they cooperate to construct a meaningful whole"* (Chourmouziadi, 2017).

To summarise, tactile experiences can benefit deeply those who handle objects inside or outside of a CH organisation. That is why touch needs to be integrated into a CH experience as it (Candlin, 2004; Jacques, 2007; Johnson, 2007; Lynch, 2008; MacDonald, 2007; Noble and Chatterjee, 2008; Phillips, 2008; Samuels, 2008):

- encourages learning not only for regular visitors, but also for those who do not usually go to museums;
- engages children in experiences with pedagogical benefits and beyond;
- agrees with regulations about universal access under the *Disability and Discrimination Act* (1995) and the more recent *Equality Act* (2010) for people who have some kind of disability;

- demonstrates therapeutic benefits (social, emotional and other) for the elderly through object-based reminiscence work;
- improves people's experiences in health-care settings, such as hospitals, having an impact on patients' well-being;
- has a beneficial impact on the morale of excluded groups, such as prisoners, who can engage in expressive collaborative activities;
- allows communities to re-engage with their past and become involved in creative and spiritual activities;
- helps people to overcome traumatic experiences of alienation and anxiety, such as the ones experienced by refugees, while working towards building resilience;
- protects sensitive objects from handling, as audiences have the chance to touch replicas which cannot be severely damaged by handling;
- agrees with the definition of museums and CH settings, as places which do not only safely guard and protect objects but communicate them to the public;
- democratises a process which is considered as the mastery of few (mainly the curators) who possess a certain institutional status qualifying them to touch.

It can be understood that such effects have a beneficial impact on individuals and communities, while potentially transforming the character of CH organisations. The possibility to touch belongs to the realm of physical, sensorial and intellectual/information accessibility (Dodd and Sandell, 1998; Solima and Tani, 2016). Accessibility's ramifications not only relate to the notions of equality and democratisation, as mentioned previously, but also advance the discourse about human rights and issues connected to political and socioeconomical challenges of our times. These discussions seem extremely important and topical; something further witnessed by recent efforts to change the definition of museums (ICOM, 2019).

At a macro level, the benefits of touching replicas and its implications are of great importance. At a micro level, though, there are still many open questions about touch and more precisely about the actual properties (tactile and beyond) of handling objects in the CH context. This is obvious in cultural studies' literature, where most research is concerned with the materiality of objects in terms of agency, ideology and concepts. These insights are valuable, nonetheless they do not complement the research by investigating the possible connections between the

properties of the replicas and their relation to the experience. Thus, studying the actual properties of objects, in terms of texture, colours, shapes, weight (to name some) and their meaning is important. Only by gaining a better understanding of such processes, can research illuminate and provide a deeper knowledge of the complexity of experiences with the use of physical objects, such as the replicas (Dudley, 2012; Spence and Gallace, 2008).

2.5.3 Tangible interaction and context-aware systems

Entering the era of *ubiquitous computing*[21] (ubicomp) has definitely affected the CH sector. Curators and designers have joined the movement in order to develop and deploy everyday objects with computational capabilities as a means of engaging visitors with a variety of ideas and content. The idea behind these efforts is to bridge the gap between the physical and the digital aspect of the experience and utilise technology that detaches the user from a specific device. By doing this, seamless computation could be extended and embedded into everyday life, bringing revolutionary changes to the way we access information without posing a threat to simultaneous interactions with other people or the environment (Preece et al., 2015, p. 55; Weiser, 1991). In addition, the "material turn" in the field of human computer interaction (HCI) already works as a theoretical and practical exploration of materiality, immateriality, the properties of things and interactions with materials (Robles and Wiberg, 2010).

Tangible interaction is a term encompassing all the aspects of interaction, emphasising the tangibility and materiality of an object which works as the embodiment of data and has the form and function of a physical interface. In the CH context, *tangible interfaces* or *tangibles* have started becoming more common and refer to physical objects that *"help bring a hands-on feel to digital interactives that would otherwise be entirely screen based"* (Diamond et al., 2016, pp. 104–105). A particular kind of tangibles in an exhibition environment are *smart objects* or *smart replicas* (when the interactive object is representing an original, whether it is digitally fabricated or not). Smart replicas usually have built-in interactive components (such as sensors, NFC tags and other) which trigger and control content complementing the

[21] Ubiquitous or pervasive computing is the age of "calm technology" where computers are pushed into the background and information is provided through devices which enter people's attention when needed in non-obtrusive ways. Such vision, as framed by Weiser in the beginning of the 90s, allows individuals to change and select activities effortless, while being aware of their environment and without posing barriers to personal interactions (Weiser, 1991).

experience with audio, images, animations and other material (Marshall et al., 2016). Currently, there is a strong research interest in HCI, heritage studies and cultural informatics with respect to smart objects enhancing multisensorial visitor experiences. The subject of investigation of a recent EU funded project (2013-2017) entitled *Material EncounterS with digital Cultural Heritage (MeSch)* was related to smart replicas. In *MeSch,* researchers collaborating with CH stakeholders studied, developed and proposed tools for the creation of tangible interactive experiences connecting "*the physical dimension of museums and exhibitions with relevant digital cross-media information in novel ways"* (MeSch, 2017).

Furthermore, *context-aware* technologies aim to support visitors with more engaging and personalised experiences by adapting content to context. Context-aware systems react to visitor preferences, movements, proximity and other actions. Such data can feed back into the experiential framework and provide real time interpretative material to suit audience needs. One of the most important contributions of these systems, in CH communication, is that they bring people closer to institutions in terms of enabling an active dialogue around artefacts and exhibitions. Thus, communication is no more a one-way process but a constant two or multi-way negotiation and interaction improving relationships between visitors and institutions (Chou et al., 2015; Seidenari et al., 2017). Recent EU funded research projects, such as *Cultural Heritage Experiences through Socio-personal interactions and Storytelling (CHESS)* explored the idea of personalisation and adaptivity of content with narrative-oriented mobile and mixed reality technologies (Antoniou et al., 2016; CHESS, 2016).

All the above technological advancements, smart objects, context-aware technologies and hybrid approaches are already changing the profile of CH institutions and the services they provide, inevitably bringing new challenges that are not merely of technical nature. Simultaneously, a number of theoretical questions and issues around the evaluation perspective of experiences arise, as it might be difficult to identify whether the new strategies and paradigms successfully contribute to a deeper understanding and appreciation of cultural heritage assets (Diamond et al., 2016, p. 105; Economou, 2016).

2.6 Audience and visitor research

Public engagement, understanding and involvement have always been demanding fields of work for CH organisations, but they have often been neglected. The attitude has changed

over the last decades, as CH organisations (Cameron, 2003; Davis, 2007; Hooper-Greenhill, 1994, pp. 54–56; Lang et al., 2009; Roussou, 2010; Watson, 2007):

- have to clearly prove measurable benefits to the public in order to get funding;
- have become aware of their social purpose and put emphasis on community needs, following the principles of "new museology" as described in previous decades; hence, organisations gradually acquire a character that is more related to services than to mastery;
- are no longer perceived as possessors of absolute knowledge, even though they retain an authoritative profile as providers of trustworthy information;
- need to demonstrate a professional approach to management processes;
- recognise that many different kinds of audiences exist which need to be prioritised and taken into consideration in decisions and designs;
- need to prove economic impact of their assets;
- have to find innovative and creative ways to enable learning through IT;
- need to be inclusive and provide access to all.

For all these reasons, over the last decades, CH organisations started to focus on accessibility and communication, by trying to approach and satisfy their audiences, while being more responsible as institutions. Until recently, the dominant idea behind audiences was this of a "general public" that engages with objects or activities within a CH organisation. The "general public" idea was based on the misbelief that a general (and average) visitor exists and has influenced -and still does to a certain extent- the way that exhibitions or interactions (physical and digital) are built (Heath and vom Lehn, 2010; Reeve, 2009). In reality, different audiences exist and serving their diverse needs and requirements can be more efficient both for visitors and the CH institution. Classifying audiences can be based on diverse criteria serving intervention and analysis purposes. Some of the most important categorisations that exist in CH literature are presented below.

2.6.1 Interpretative communities

Hooper-Greenhill (1999b, pp. 49–50, 2007) has suggested that CH institutions are places where different *interpretative communities* meet. These communities:

- are categorised and perceived in relation to the interpretation process;

- share common frameworks of intellectual skills and interpretive repertoires;
- are fluid as their members could belong to many communities at a time.

Even though it might be difficult to identify them, the concept of different interpretative communities has helped CH institutions to form their strategies and plan their activities. Mason (2005) and Watson (2007) have extended the concept of interpretative communities and suggested audience groups can be defined by:

- Their shared historical or cultural experiences: These communities might constitute ethnic minority visitors or groups of people who share a common cultural view with respect to objects, themes or exhibitions.
- Their specialist knowledge: These are usually groups whose common characteristic is an advanced knowledge about an exhibition or field and have a variety of levels of understanding an object or theme.
- Identities, such as national, regional, local or relating to sexuality, gender: Visitor behaviour and interpretation can be affected by a variety of reasons related to the provenance of people, their age and their perspective based on gender or sexuality.
- Other demographic and socio-economic factors: This is the way that most museums identify visitors by analysing data such as education level, ethnicity or household income. Further information relating to identities (see previous group) can also be included here.
- Visiting practices: The type of visit also influences interpretation, which might defer if someone visits a CH setting alone or as part of a group and also depends on a variety of sociocultural factors.
- Exclusion from other communities: Communities which for several reasons are or feel excluded from CH institutions.
- Location: A CH institution might define its communities by geographical location on a local, regional, city and other area basis.

It is easily understood that interpretative communities can be fluid and members of one group can intersect with the members of another or exist in many groups at a time based on situational parameters. A characteristic example that Mason (2005) deploys is about the members of a local football team who also support the national team, when an international game happens.

2.6.2 Model of visitor-identities

The model of *visitor-identities* is considered by Falk (2016; 2013, pp. 47–52) as a more psychographic approach that seeks to understand how self-related reasons -such as motivations, previous experience, interests- might help to identify museum goers. The approach recognises that demographics might be used to depict CH visitors, nonetheless demographics cannot sufficiently describe the variety of visitors who might visit a museum not just because they are men or women, live locally or afar, but rather because they have a set of reasons. Based on Falk's classification there are five common categories of visitors and two which complement the list as they represent more identity and ethnic oriented groups. However, identities can also be fluid as a visitor might behave in one way today but in another way when visiting another exhibition. Falk's identity related groups are presented in table 2.

Identity	Details
Explorers	They feel curious and seek opportunities for learning. They are interested in museums and want to explore them to find attractive objects or collections.
Facilitators	Their motivation is of a sociocultural nature. They usually come to a CH institution with a group, which they want to guide and help to learn.
Professional/hobbyists	They have a special interest in a collection or might have some kind of professional connection to an object or exhibition.
Experience seekers	They primarily go to a museum because they "have to" visit this destination. They seek for experiences but are not necessarily attracted to a specific theme or collection.
Rechargers	They want to find ways to "charge" their energy by avoiding the clutter of everyday life. Museums trigger their spiritual and intellectual needs and help them to fulfil their needs.
Respectful pilgrims	They have a feeling of obligation to go to a CH setting, which is a sort of pilgrimage, to honour people, memories or events.
Affinity seekers	Similar to the above group but this time the visit is directly related to the heritage, identity and personality of the individual.

Table 2: Falk's visitor-identity groups.

Falk's model has been recognised as a valuable insight into the motivational aspect of the visit. However, it has received criticism especially by Dawson and Jensen (2011) who argue that visitor segmentation approaches, such as Falk's, are not pluralistic enough and cannot reject demographics, whose relationship with behaviours, attitudes and experiences has a proven value. A certain consensus regarding the deployment of demographic data along with

self-related reasons (visitor-identities) has been achieved in a collective paper, where all authors agree on the value of an inclusive approach (Jensen et al., 2011).

2.6.3 Target audiences

A museum can identify members of a community or communities as a *target audience*, a concept which is closely related to the *target group* concept originating from market research. In market research, though, target groups can be described with great detail and behaviours can be even predicted especially with respect to product choices. In the CH context, target groups are perceived in more flexible terms and in relation to parameters, such as ethnic origin, class, age, education, disability, location and other criteria. Often, target audiences include: random visitors, families with children, visiting schools, senior citizens, foreign visitors and other (Hooper-Greenhill, 1994, pp. 85–88).

Even if it seems difficult to grasp a specific group, by selecting audiences it becomes possible to design specific activities -for instance using digitally fabricated artefacts- in ways that will be more receptive for certain people (Davis, 2007). Besides, as Hooper-Greenhill states *"making provision for common needs, and reviewing the museum experience from the point of view of each target group, will go a long way towards enabling most people to enjoy museums"* (1994, p. 84). Hence, an important element to remember, when selecting target audiences, is that an "inclusive" strategy should be employed. This means that target groups work rather as a variety of approaches to communicate CH information than as definite communication strategies.

2.6.4 Mosaic

Mosaic is a consumer classification system, designed by *Experian*, segmenting population into fifteen groups and sixty-six types. Mosaic has been used in a variety of contexts and is a powerful system that has also been deployed in the CH sector. The system's previous versions (version 2009), along with other classifications (*Spectrum*) and socio-demographic analysis, have been used by RPM in order to analyse visitor data. Mosaic's fifteen groups and subgroups based on the more recent release from Experian are presented in table 3 (Experian, 2016; The audience agency, 2010).

Group	Details	Types (subgroups)
City Prosperity	Well-educated people, live in central urban areas and have high salaries, offering them the chance to enjoy a luxurious life.	World-class wealth, uptown elite, penthouse chic, metro high-flyers.
Prestige positions	Married couples with successful careers, financial security and large family homes.	Premium fortunes, diamond days, alpha families, bank of mum and dad, empty-nest adventure.
Country living	They leave in the countryside. They might be landowners, farmers, work from home or even commute to cities to work.	Wealthy landowners, rural vogue, scattered homesteads, village retirement.
Rural reality	People who live in rural areas and own small businesses or work in the local area. They have relatively low incomes.	Satellite settlers, local focus, outlying seniors, far-flung outposts.
Senior security	People of an older age who still live in family homes (after their children have left) or in places with people of the same age.	Legacy elders, bungalow heaven, classic grandparents, solo retirees.
Suburban stability	Couples or families with adult children who are still family-supported and live with their parents or pre-retirement couples enjoying greater freedom since children left.	Boomerang boarders, family ties, fledgling free, dependable me.
Domestic success	Families with high incomes living in desirable residential areas enjoying comfortable lives.	Cafes and catchments, thriving independence, modern parents, mod-career convention.
Aspiring homemakers	Single people or young families who recently bought or are ready to buy a modest house in suburbs.	Primary ambitions, affordable fringe, first-rung futures, contemporary starts, new foundations, flying solo.
Family basics	Families with low incomes who struggle to maintain themselves. Family basics live in areas with low-cost housing.	Solid economy, budget generations, childcare squeeze, families with needs.
Transient renters	People in their 20s and 30s with low-skilled jobs. They rent small cheap houses or share accommodation with people of the same age.	Make do & move on, disconnected youth, midlife stopgap, renting a room.
Municipal challenge	They live in social housing, have low incomes and often receive benefits. They are single or have families.	Inner city stalwarts, crowded kaleidoscope, high rise residents, streetwise singles, low income workers.
Vintage value	People of an older age who possess different levels of independence. Some of them live in their home while others move to care homes.	Dependent greys, pocket pensions, aided elderly, estate veterans, seasoned survivors.
Modest traditions	People of a certain age living in their own expensive houses are the members of this	Down-to-earth owners, offspring overspill, self-supporters.

Group	Details	Types (subgroups)
	group. They do no not have high qualifications or jobs but enjoy a standard way of life.	
Urban cohesion	They enjoy community life in suburbs with cultural diversity. Urban cohesion's members are older people or families coming often from a South Asian background.	Community elders, cultural comfort, Asian heritage, ageing access.
Rental hubs	Single people in their 20s and 30s who rent homes and are in the early stages of their career.	Career builders, central pulse, flexible workforce, bus-route renters, learners & earners, student scene.

Table 3: Mosaic audience groups.

2.6.5 Personas

When creating *personas* CH professionals and designers try to depict various archetypical CH audiences. Personas are fictional characters, representing different visitors whose characteristics are analysed in order to shape the design of an exhibition or activity. Usually a representative picture is selected to depict the persona, a name is given to him/her and a narrative describes the story of the person, his/her occupation, preferences, requirements in the context of the designed application or product and so on. The process is considered as one of the standard user-centred design methods as it attempts to build understandings of potential visitors as well as to identify and address a variety of challenges, behaviours and goals with respect to user groups (Miaskiewicz & Kozar 2011; Avram & Maye 2016, p.28).

The concept and design method of personas has been deployed within the framework of EU-funded heritage research. For instance, *CHESS* (2016) used personas to create experiences that combine storytelling and personalisation for the *Acropolis Museum* in Athens, Greece and the science centre, *Cité de l'espace* in Toulouse, France (Roussou et al., 2013). Another approach with respect to personas was developed under the project *EMOTIVE* (2019). Researchers of the EMOTIVE project developed group personas in order to address the social complexity of a CH visit, while promoting interactions between and within the members of visiting groups through emotional narratives (Economou et al., 2017; Mirashrafi et al., 2017).

2.6.6 Audience spectrum

Another popular audience segmentation system designed by *The Audience Agency* company on behalf of the *Arts Council* (UK) is *Audience spectrum*. The system has also been used by RPM along with other classification systems and analysis of socio-demographic data for their

visitors. By doing this, the analysis of RPM takes advantage of Spectrum's profiles, without excluding other types of data interpretation which might witness different ideas, opinions or aspects of audiences' visits. Audience spectrum segments the population of the UK in ten profiles, describing the different types, lifestyles and interests of museum and CH visitors. In this sense, Audience spectrum is close to Falk's model of visitor-identities as well as Culture segments classification which is also presented subsequently. Audience spectrum's profiles (The Audience Agency, 2014) are presented in table 4.

Profile	Details
Metroculturals	Well-educated people who mostly enjoy arts and have a busy urban lifestyle. They have a wide range of interests and engage with opportunities for creative activities and innovative ideas.
Commuterland culturebuffs	People with managerial jobs who usually leave in suburban areas and seek for learning and self-improvement opportunities. They enjoy culture but have more conventional tastes.
Experience seekers	People, usually of a younger age, who engage actively with culture which forms an important aspect of their lives. They have diverse interests and want to enjoy a variety of experiences as part of their social lives.
Dormitory dependables	Mature couples or older families who regularly engage with CH activities. They perceive heritage experiences rather as social outings and occasional activities and not as intrinsic part of their lives.
Trips and treats	They live in suburban areas and enjoy a variety of leisure activities. They are influenced by popular culture and are led by children's interests. They engage with arts without demonstrating a passion for the sector.
Home and heritage	People of a certain age with traditional tastes. They often engage with local activities to satisfy their interest in nature, history and local events.
Up our street	Modest people with relatively low incomes who have stable lives and enjoy museums, art and popular entertainment. Some of them are older and encounter health problems.
Facebook families	They are of a younger age and live in semi-urban areas of high unemployment. They do not consider arts and culture as a crucial part of their lives. They mainly enjoy cinema, live concerts and eating out.
Kaleidoscope creativity	People who do not engage that often with culture. They have a variety of cultural backgrounds, employment and ages. Their low incomes do not allow them to access easily CH activities. They mostly engage with local outdoor free events.
Heydays	Older people who often live in accommodation for people of their age. They do not engage that much with CH experiences in museums or events, but enjoy participatory activities related to crafts and arts in local centres, churches or groups.

Table 4: Audience spectrum groups.

2.6.7 Culture segments

Culture segments is a classification system, designed by the research consultancy company *Morris, Hargreaves and McIntyre*, especially for CH organisations. The system is based on people's cultural values and motivations which have the power to define lifestyles and behaviours. Hence, it is closer to motivation schemes, such as Falk's model of visitor-identities. The presentation of a more holistic analysis might be an advantage of this segmentation, nonetheless in many instances it is combined with more data analysis techniques (plain socio-demographic analysis) in order to reveal multiple aspects of visitor behaviours. The eight segments which are included within the market of CH are presented in table 5 (Morris Hargreaves McIntyre, 2016).

Segment	Details	Keywords
Enrichment	Older people who live close to the CH setting and have specific likes which are related to their heritage, traditions and way of life.	Mature, traditional, heritage, nostalgia.
Entertainment	Adults of a younger age who see culture as an addition to their everyday life and usually visit must-see exhibitions or events.	Consumers, popularist, leisure and mainstream.
Expression	Creative and expressive people. They like to connect with the community and have a wide range of interests.	Receptive, confident, community, expressive.
Perspective	Home-oriented, settled people. Arts and culture are not their highest priorities, they are though interested in learning and in this way, they engage with CH.	Settled, self-sufficient, focuses and contented.
Stimulation	They like to be stimulated and want to enjoy a variety of experiences including novel exhibitions and technological advancements.	Discovery, experimental, active and contemporary.
Affirmation	Young people who enjoy culture and want to improve themselves and their children through it. They care about other people's opinions and they perceive cultural visits as a status activity.	Self-identity, aspirational, quality time and improvement.
Release	People with busy lifestyles who like arts and culture but have prioritised other sectors in their lives. When they have some free time, they prefer to socialise outside of the CH context.	Ambitious, prioritising and wistful.
Essence	Well-educated people who perceive CH activities as an essential part of their lives. They want to engage with exhibitions and cultural events as often as possible and like to "show the way" to others.	Spontaneous, discerning, independent and sophisticated.

Table 5: Culture segments classification system.

2.7 Narratives and experiences

Based on the topic of this research, it is meaningful to discuss about the nature of *experiences*, which are fundamental for all learning-related processes and beyond. Experiences affect and form our knowledge, values, emotions, attitudes, beliefs and behaviours. In the CH context, experiences (or better *experiential frameworks*) can employ a digitally fabricated artefact amongst other interpretative means. Such experiences always involve narratives as part of their design and expression. These are stories that might be connected to an artefact or artefacts and present aspects of its creation, events related to it, information about its purpose and so forth. The following sections are dedicated to a discussion about the nature and importance of experiences and narratives focusing on the CH aspect.

2.7.1 Narratives or stories

Amongst the most important responsibilities of museums and cultural heritage organisations, apart from documenting and preserving their collections is to communicate them to the public for the purposes of education, study and enjoyment (ICOM, 2007). Such an important duty should be placed in the hands of museums which are accessible to all and have strong communicative objectives.

Nevertheless, CH organisations do not always succeed in fulfilling their communication role and many people maintain an attitude of "distant admiration" towards them. In a plethora of museums, objects are presented as design pieces or distant objects without any context. Thus, they represent a kind of "trophy" that is only accompanied by a short note, providing some information about their provenance, chronology or creator, without really enriching our understanding and appreciation about our past or the world around us. Even though some authors suggest that artefacts have a power of their own (Dudley, 2012) and have the capability to engage visitors in a CH exhibition or site *per se*, it is more significant to deploy their potential within interpretative frameworks. Obviously, providing interpretative information is a critical issue if museums and CH institutions do not wish to be perceived as models of fragmentation, supporting curatorial approaches that are concerned only about the object and ignore the audience. To this purpose, narratives can serve as powerful tools to reclaim the CH organisation and its potential, while supporting the visitor in making sense, experiencing and enjoying things in CH settings (Kelly, 2010; Lohrey, 2010; Pine and Gilmore, 2007).

In explanatory terms, a *narrative* can be described as a story that: is structured as a series of events, states and happenings; involves human beings; and is arranged in time from the inception of the drama to its conclusion. It should also be mentioned that *plot* is another component of narratives. However, plot puts emphasis on the causes and effects of a story. Thus, plot explains why actions or facts evolved in a certain way and events followed a specific sequence. Some people might further think that a story is a work of fiction, but that is not necessarily true, as stories might include real or fictional facts (Handler Miller, 2004, p. xiv). Other people suggest that a story is just the sequence of events while the narrative deals more with how these events are synthesised (their structure) and thus is closely related to the plot (Branston and Stafford, 2010, pp. 42–43). In the frame of this thesis, the word *story* is perceived in a broader sense and is used interchangeably with the word *narrative*, as both stories and narratives are closely woven and constitute important "ingredients" of a CH experience. The narrative in a CH environment or site might revolve around an individual object that belongs to a collection. The narrative will present the object's story with a certain level of detail under a theme. It might also include multiple objects from a collection and present their stories or aspects of their stories under a theme. A narrative can only capture one or some of the stories around an object and certainly cannot represent all possible views.

Telling a story is one of the oldest activities and still amongst the most powerful ones in terms of engaging people with content that is somehow structured. This happens because narratives are fundamental in the ways human beings understand and learn about the world (and thus about CH). As Bruner (1986, pp. 11–13) suggests, the way that people think follows either a *paradigmatic/logico-scientific* mode or a *narrative* mode. The paradigmatic/logico-scientific mode employs categorisation and conceptualisation and includes operations that are established and connected to form a system. The narrative mode follows a different process to verify and corroborate something. A narrative can be described as a good story that verifies something, whereas the logico-scientific mode works as a good argument to verify something. Hence, narratives provide explanations of the relation between a set of objects and events; explore human intentions and actions, vicissitudes and consequences that mark a course of thinking. Of course, this does not mean that there is not a synergy between the approaches, as they complement one another and describe the diversity of human thinking (Bedford, 2001; Bruner, 1986, pp. 11–13).

The power of stories has led many CH professionals to gradually adopt the narrative approach to engage audiences with collections. Narratives can constitute essential tools in outlining the framework for valuable CH experiences as they (Bedford, 2001; Bruner, 1990, pp. 47–50; Cameron, 2010; Glover Frykman, 2009; Lohrey, 2010; Mytilinaiou, 2015, pp. 212–216):

- Provide meaning about the world and ourselves: Narratives help us make sense of the world and understand our lives. Narratives work as means that allow us to create an identity and find a place in this world.
- Inspire social interaction and create togetherness: Narratives can inspire social interaction between users. They can also generate personal connections between audiences, objects, collections and other data that describe practices, lives, memories etc.
- Provide a structure for remembrance: Narratives structure information in a way that, even if it is less formal or less informational, stays in our memory and is more difficult to be forgotten.
- Have strong emotional impact: Narratives can provide the means for strong emotional experiences. People might engage with the content of a narrative strongly and experience feelings that can even change them at a personal level.
- Inspire internal dialogue and form our personality: Stories open up a space where thoughts, feelings and memories can be discussed and expanded. Thus, they offer deeper understanding of what is important to us.
- Are open to multiple opinions, values, practices: A narrative can deal with the canon -what we have been taught is right or true- and the exception. Whatever happens in a story -moral or not- might help us understand the world and form our beliefs. In the CH field, this is important when we discuss about artefacts that come from different historical periods or societies with different moral values and practices.
- Reinforce participation: Stories enable people to imagine themselves in other distant, past or future worlds. Moreover, narration might actively involve people trough interaction, dialogue or merely emotional, cognitive, compassionate empathy.

- Help curators and other CH professionals to accomplish their goals: Narratives can be deployed in many ways to communicate and discuss CH information, engage visitors and help them to appreciate artefacts, collections and CH sites.
- Complete the needs of different audiences: Both stories about an object and stories that relate multiple objects can be adapted or especially designed to satisfy the needs of different audience groups.
- Form part of our culture: Narratives are always a product of cultural, disciplinary, museum, curatorial, political decision. They are an essential part of every community and not only transmit histories, values and beliefs, but shape cultural products as interpretative frameworks for experiences.

Qualities, such as the ones enumerated above justify the power of narratives. Their potential to investigate the dynamics of replicas can be significant. Therefore, it is important to understand how replicas can be incorporated into cultural heritage experiences which ultimately tell a story, a narrative that different audiences understand and enjoy through positive and valuable experiences.

2.7.2 Experiences

Experiences constitute the basis of our lives. Experiences have internal aspects and external explanations/expressions. Experiences are complex phenomena that are difficult to grasp, decode and communicate. Nonetheless, interactive experiences (in the broader sense, not necessarily involving IT) are the basis of knowledge, based on the Piagetian *constructivist* theory of knowing. As Jensen (1999) explicitly states: *"knowledge is acquired in a continuous process of accommodating prior expectations and beliefs to new realities learned through interactive experiences"*. Investigating experiences has always been an interesting field of study for researchers trying to explore and possibly explain decisions, incidents and trends.

In the CH context, people often discuss about the *provision* of experiences to visitors or audiences. However, it should be made clear that experiences cannot just be delivered. A curator can design an *experiential framework*, but the way that this experience is lived and perceived belongs to the sphere of the visitor himself. Hence, whenever experiences are discussed in this thesis (even when phrases such as "deliver experiences", "design experiences" are used), they are understood as something that actively evolves and constantly changes in the minds and hearts of visitors. Such a stance agrees with the *relativist*

constructivist theories (where knowledge -or better knowledges- and understanding are always constructed and related to a variety of contextual factors) and the focus of the museology community that turned to the discussion of experiences soon after the beginning of the 90s. The difference is that now experiences: can have multiple meanings and interpretations; acknowledge the influence of prior knowledge and expectations; often present contradictory information; focus on the ideas of inclusion and accessibility which is not only physical, but also conceptual, multisensorial and intellectual. Such changes had and still have design implications with respect to the exhibits introduced in museums and CH organisations as "experiential offerings" within mediated environments to satisfy all or some of the above requirements (Roppola, 2012, pp. 18–32).

In this study, experience uses as a starting point Falk's and Dierking's concept of *contextual learning*, that was based on a number of similar efforts to schematise experiences and learning (see section 2.8 and section 4.4.1) (Falk and Dierking, 1992, 2013). Therefore, experiences are multidimensional and are perceived as the constant constructive dialogue between a series of contextual factors, such as the *sociocultural*[22], *physical*[23] and *personal* context[24]. Experience is also expressed through a broad definition of learning which encompasses enjoyment and entertainment decoded into behavioural, emotional, attitudinal, knowledge, skills and interest effects in visitors' lives (Arts Council England, 2014a; Falk et al., 1998). Within this framework, experiencing a replica can be considered as a first-hand act of involvement with the physicality of an object which has the potential to enhance learning and appreciation. However, this act should imply and create connotations with actual life experiences (or agendas), as described in Hein's work (2004) about Dewey's deep influence on museum learning.

[22] The social context pertains to the composition of a group or the individual visitor and the social interactions that happen during a CH experience. It also encompasses -on the broader sense- the societal and cultural status of the experience (i.e. it might be a socially recognised activity to visit a museum).

[23] The physical context includes the place that people choose to visit and its feeling, the contents of an exhibition, the digitally fabricated artefact that supports the CH experience and other elements.

[24] The personal context describes the unique characteristics of the cultural heritage (CH) visitor and includes the "perceptual burden" and "agenda" that he/she brings to the experience (such as previous knowledge or motivations).

Another fundamental principle about experiences is that they are co-produced. Audiences and exhibits interact on the experiential platform of a museum, CH setting or event generating subjective experiences (Roppola, 2012, pp. 43–47). Whether subjective experiences use real objects is a matter of thought. In today's museological landscape, *realness* and *authenticity* tend to move away from the object itself and refer to experiences, which can only be authentic as they happen inside us and have the ability to "render" authenticity around us (see section 2.3.3) (Hede and Thyne, 2010; Pine and Gilmore, 2007). An open question though is how to maximise these experiences to benefit audiences in terms of successfully engaging them and how the situational (contextual) factors can contribute to this direction. In the context of this thesis, study also expands as much as possible to the semiotics connecting the material representation (the digitally fabricated artefact) with the experiential context.

2.8 Evaluation in the CH context

Evaluating the deployment of technology in the CH context has a long history. In literature, various models and reports reflect the ongoing efforts of the sector to provide effective ways to measure the outcome of audiences' experiences with digital resources or assets that combine the digital and the physical world. Some of the evaluations might take place before the development of a programme in order to understand how audiences would respond to it (front-end evaluation). Another type of evaluation includes measuring responses while the development of a programme takes place or when an exhibition has been launched, usually focusing on finding out pitfalls and improving the resources to maximise positive visitor experiences (formative or remedial evaluation). When evaluating a programme to understand its impact to visitors after the completion of the design of an exhibit or activity and the opening of an exhibition, then that is mentioned as summative evaluation (Diamond et al., 2016, pp. 3–4; Economou, 2003, pp. 107–110). Depending on the type of technology or product that is used within the CH context, the above described set of evaluations might incorporate or combine elements of HCI research, such as usability testing, functional testing and experiments that usually take place in controlled settings with users; field studies deploying a variety of methods in natural settings with real users; and inspections, models, walkthroughs and other methods used in any setting (Preece et al., 2015, pp. 456–462).

In informal learning, museum and visitor research literature, a number of models, concepts or frameworks to conduct evaluation of interpretative resources and exhibitions exist. Some of these examine the effectiveness of resources, their impact or learning outcome regardless of whether they include technology or not. Amongst the most important ones, that have also largely influenced this research (along with input deriving from other disciplines such as product design and psychophysics, see Chapter 4), are the *Learning Impact Research Project* (Hooper-Greenhill, 2004), the *Framework for Evaluating Impacts of Informal Science Education Projects* (Allen et al., 2008), the *Generic Learning Outcomes* as suggested by the *Inspiring Learning for All* framework of the *Arts Council* (Arts Council England, 2014a; Museums Libraries and Archives Council UK, 2008) and the *Interactive Museum Experience* model as introduced by Falk and Dierking (1992), called *Contextual Model of Learning* in the revised version of their book (Falk and Dierking, 2013). The invaluable contribution or these frameworks is that not only they "decode" or describe the ecosystem of CH experiences, but they also provide a sensible classification about the ways that such experiences can be investigated and measured.

Another part of the literature focuses particularly on the digital aspect of CH and examines ways to understand whether IT tools and applications effectively engage audiences and support interpretation. For instance, the *MUSETECH* framework (Damala et al., 2019) examines museum technology before and after the introduction of the digital elements in a museum setting. MUSETECH establishes three entities-perspectives: the CH professional, the museum and the visitors. The model introduces an extended matrix that examines museum technology by deploying sets of "evaluation criteria" attributed to the phases of design, content, operation and compliance for each specific entity. The model has been tested within three case studies (interactive exhibits and large-scale exhibitions) and has provided useful insights with respect to the impact of technology. MUSETECH "living" model, as the authors conclude, can be further tested within different contexts to find out how it can be modified, enriched and adapted according to other types of installations and research questions.

A further framework that emphasises strategies, processes and technologies to engage all involved stakeholders from the CH organisation including audiences is the *Digital Engagement Framework (DEF)* (Visser et al., 2013). The framework defines a set of ten categories that address the whole range of questions -both "visionary" or "operational" as

the authors call them- related to digital engagement strategies. The framework, apart from structuring and advising on how to build a digital strategy, also proposes ways to measure people's engagement by examining quantitative data (online metrics, such as page views, likes, shares etc) and qualitative information that is often quantitatively analysed (e.g. percentage of visitors that spent some time online, clicks through topics in newsletters and other). The DEF can be very useful to practically assist professionals in the CH sector in defining and developing strategies, however it is mostly devoted to the online presence and performance of an organisation without focusing on on-site engaging experiences.

Customised frameworks and reflection on evaluation schemes also exist in the CH literature and practice. Such frameworks can be tailored to specific projects and their related research questions or specific types of technology. For example, the researchers of the EU-funded project *V-MusT.net* (V-MusT.net, 2015) identified practices and developed criteria to evaluate usability, portability and integration of a variety of IT applications and installations in museums participating in the project (Reuter and Granier, 2014), while deploying standard methods to evaluate digital resources and reflecting on them (Pescarin et al., 2012). Similarly, the *EMOTIVE* EU-funded project (EMOTIVE, 2019) focused on the emotional engagement of visitors when interacting with digital interpretative narrative content. The researchers of EMOTIVE tailored an evaluation framework to support the project's needs and combined traditional usability and HCI investigation methods with creative techniques and mixed method approaches, as used in museum and visitor research (Economou et al., 2017, 2019).

A number of efforts have also been done to examine how evaluation can respond to specific types of technology or platforms. For instance, Winter (2016) examines how interactive social object label displays can support audiences in engaging with digital annotations of physical objects in exhibitions. Other researchers evaluate the social-media performance of CH institutions by deploying and critically assessing already existing frameworks. Fleming et al. (2016) examine *Culture24*'s evaluation principles or framework as presented in their reports, also addressing web and mobile engagement apart from social media (Finnis et al., 2011; Malde et al., 2013). Villaespesa (2015), on the other hand, examined how the *Balanced Scorecard* evaluation framework, which was initially designed for the business sector (Kaplan and Norton, 1992) and then modified for non-profit organisations (Kaplan, 2001), could be adapted to evaluate the social-media strategy and performance at the *Tate*.

The above list of frameworks and examples cannot be exhaustive and in reality, more frameworks or application examples exist or emerge. This demonstrates how active the discourse in this field is, reflecting somehow the speed with which new technological advancements appear and are "tested" within the CH sector. At the same time, all these examples demonstrate that consensus with respect to evaluation has not yet been achieved and, even though most proposed methods have been broadly deployed, adaptation and customisation on a case-by-case basis is almost every time necessary (Economou et al., 2019).

The following section moves forward to examine specifically the evaluation of replicas as interpretative means in the CH context and discusses relevant examples.

2.8.1 Evaluating replicas

Digitally fabricated artefacts have been recently introduced to communicate information within interpretative CH scenarios. To date, there are not many evaluation reports in literature regarding replicas in experiential frameworks. Most examples talk independently about methods coming either from the field of computing or museum and visitor studies. In other cases, replicas are examined within experimental setups without an in-depth consideration of the variation of audiences and the complexity of contextual factors as they exist in realistic interpretation scenarios. Hence, little has been done to aggregate both theories and methods in order to address both the physicality of replicas and their meaning-making ramifications.

When discussing about the *Museum3D* programme at the *Art Institute of Chicago*, Neely and Rozner (2015) state that the evaluation included quantitative and qualitative methods to assess visitor engagement with 3D activities including replicas, their impact on people's discernment and factors influencing the programme's efficacy. The physical characteristics of replicas are mentioned in their qualitative analysis as "engagement vehicles", without further examination. On the other hand, Di Giuseppantonio Di Franco et al. (2015) examine some physical qualities of replicas such as weight, colour, size and texture within an experimental set up by investigating whether the presentation modalities (VR experience, viewing of original artefacts and handling of replicas) affect our perception and understanding of CH.

Marshall et al. (2016) and Damala et al. (2016), when evaluating the use of smart (interactive) replicas to provide further layers of information to visitors of two exhibitions realised under the MeSch project (MeSch, 2017), examine digitally fabricated artefacts along with replicas

produced in other ways. The MUSETECH framework seems to have been used for the evaluation of the MeSch project activities (Damala et al., 2019) and, with respect to replicas, both qualitative and quantitative data are collected to assess usage, interaction, social patterns, learning and emotional impact. Marshall et al. (2016) also refer to the "qualities" of replicas (whether digitally fabricated or not) and mention that it was the narrative's perspective each replica was connected to, which played a role in visitors' selection, along with the overall design and general appearance of the object.

Another part of the literature is dedicated to the experiences that visually impaired audiences had with replicas, because this has been recognised as one of the audiences that can benefit the most from replicas (see 2.4.5). When examining tactile paintings given to visually impaired people, Neumuller et al. (2014) refer to some evaluation techniques. More specifically, they mention the "materiality", texture and weight aspect of the object, which can also be "reflected as metadata" when creating a tactile replica, without though further analysis. Similarly, Reichinger et al. (2011) talk about depth, texture and composition with respect to tactile paintings, stating that a more comprehensive study should be planned for the future. In future evaluations of tactile replicas with blind and partially sighted visitors, Reichinger et al. (2016b) assess participants' feedback using both quantitative and qualitative methods focusing on the materiality (meaning the material used for the production of the object) and interaction with replicas. In another of their latest publications, Reichinger et al. (2016a) analyse further the techniques used to evaluate a gesture-based system to experience tactile paintings. These techniques are of quantitative nature and reflect the traditional aspects of user experience (UX) with regards to usability, utility, functionality, aesthetics, identification, stimulation and value. In like manner, Carfagni et al. (2012) evaluate tactile paintings with visually impaired users by deploying quantitative methods focusing on the readability, recognition and comprehension of objects after explorations with a decreasing difficulty level. Anagnostakis and Antoniou (2016) also evaluate a system to assist blind and partially sighted people when experiencing full 3D replicas in museums deploying observations and interviews. However, they mostly focus on usability which is measured in terms of task success, time and number of errors.

Research coming from the discipline of product design by Elvin Karana and her colleagues (2010; 2009, 2010) investigates the properties of materials by deploying *magnitude*

estimation measurements (see 4.5.3) and assigning meanings to materials and objects, which might feel nostalgic, aggressive, toy-like and so on. Their research considers context as an existing "umbrella", which might be difficult to capture and explain. Petrelli et al. (2016) move a step further to explore the aesthetics of tangible interaction, by including forms (shape, material, size) and behaviours in their investigation of hybrid objects. The results of this research could be further expanded to design smart replicas that will be used within specific contexts to satisfy specific purposes.

Finally, two of the latest research efforts that are dedicated to replicas need to be mentioned here. The first one is a report from researchers in the University of Stirling along with academics and colleagues from Scotland and Europe. The report proposes principles and general guidance regarding the significance of replicas. In more detail, the report suggests useful topics to examine when investigating the value of replicas (both traditionally made or technology mediated), agrees about the importance of contextual parameters, while also emphasising that *"an understanding of how senses connect through affect and performance can aid replica presentation and interpretation strategies"* (Foster and Jones, 2020).

The second recent work comes from Wilson (2017, 2018) who attempts to address the overall question of replicas' evaluation, while focusing on what kind of replicas do museum visitors prefer. This study employs a mixed methods sequential design, while extensively using statistical analysis. The research demonstrates, through an experimental museum setup that compares replicas of a natural specimen made of different fabrication materials, what are the most important aspects that visitors pay attention to, when encountering a replica. Thus, it concludes that *verisimilitude*, *robustness* and *quality* are the most important factors that people appreciate when examining a replica. While some of these aspects are also highlighted in the current thesis, it seems that the focus of the previous-mentioned research is mainly driven by technology and the richness of a CH experience might not have been adequately captured. Hence, the lack in contextuality both in terms of a realistic experiential scenario and with respect to audience segmentation, can largely affect the effort to generalise results (as supported by the design of the study). Finally, the research concludes that more efforts are needed in order to cover the knowledge gap: in recording and analysing the learning and overall user experience people have with replicas; in examining particular audiences' needs (such as the visually impaired); in understanding how people regard the physical properties

of replicas, authenticity and other modes of representation; and in identifying the requirements of varied audiences.

By looking at all the above examples it becomes obvious that the evaluation of experiences deploying replicas is an active and evolving field of research. Nonetheless, there are topics that still need to be investigated. Furthermore, when examining the experiences that people have with replicas which are used as interpretative means, several considerations with methodological implications exist. Hence, the effort in this thesis focuses on addressing -as much as possible- holistically the questions around replicas and their effectiveness to support visitor interpretation within realistic scenarios.

2.9 Summary

This chapter detailed some of the most important aspects and theoretical foundations that frame the research and this thesis. Examples from literature were presented in order to contextualise, identify and discuss the topics, revolving around: replicas, their role, function and contribution within CH experiences for audiences, as well as the evaluation strategies involved in replicas' examination.

The research can be considered topical in terms of coinciding with recent efforts that investigate issues around the existence of replicas in heritage settings. Moreover, the technological hype cycle of digital fabrication demonstrates that the educational and learning potential of the technology seems promising, but still needs to be based on further investigations and evidence. This remark is also supported by the fact that currently a great number of applications deploying replicas in the CH experience exist, presenting a variety of engaging activities for audiences and an opportunity for CH institutions to become more accessible and open. However, such opportunities need to take into consideration audience's perceptions, interests and trends, as described in the field of visitor research. In addition, all efforts need to be based on the idea of inclusive experiential frameworks, acknowledging that a unique truth does not exist. What is true though is what everybody lives, understands and feels when facing, touching and exploring a replica within highly contextual situations.

The next chapter of the thesis is dedicated to the methodology that was adopted for the development of the research and examination of its results.

3 Chapter 3: Methodology

3.1 Introduction

The purpose of this chapter is to present the methodology employed for the research. The research framework is presented in the first instance to describe principal theoretical perspectives. Then, the rationale of the research is described along with information on the design of the case studies. Figure 7 provides an overview of the methodology and design of the research, which: a. deploys the *multiple-case study* design to address the research questions; b. selects apposite data collection methods in order to gather evidence of qualitative and quantitative nature; c. analyses the results within each case study and then examines similarities in an across-case manner in order to present conclusive findings and examine applicability.

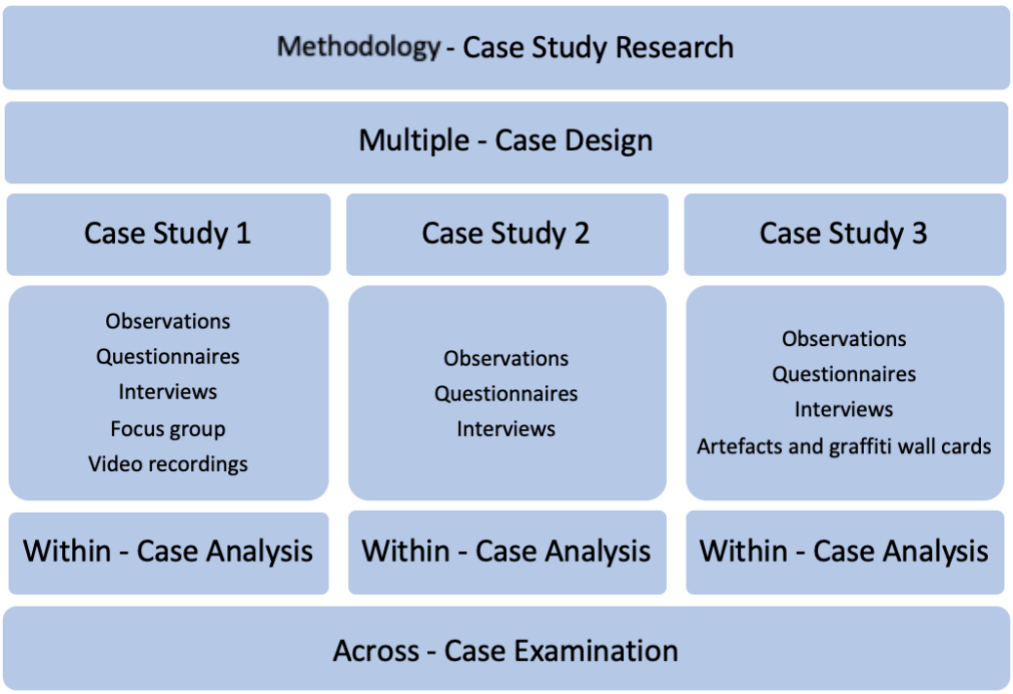


Figure 7: Overview of research methodology, design, methods and analysis.

The chapter also provides details on further methodological considerations with respect to sampling participants, saturation of data, triangulation, authenticity and comprehensiveness of the research.

3.2 Research framework

This research project investigates the properties of digitally fabricated artefacts and their dynamics within interpretative frameworks in order to assess their attributes and propose ways to successfully produce and introduce them in experiences for audience groups. This subject of investigation emerged following a period of study on the discourse around the introduction of fabricated artefacts in the CH domain. During this period, it became obvious that there is a clear gap in research and absence of evidence that would justify and propose ways to design, produce, incorporate and evaluate replicas within interpretative scenarios to communicate CH information and enhance visitor learning, enjoyment and appreciation of a heritage object, collection or exhibition.

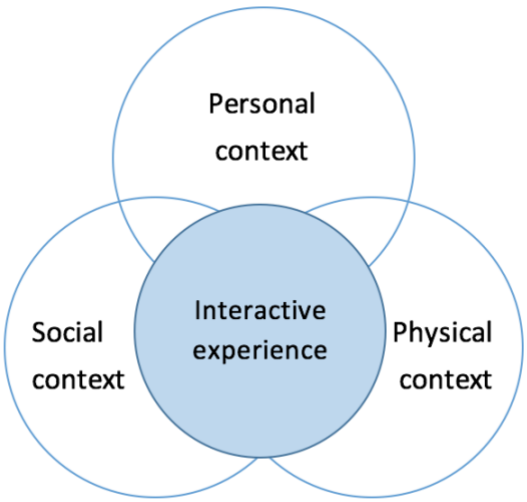


Figure 8: Falk and Dierking's "Interactive Experience" model (1992, p.5).

To respond to this knowledge gap, the research draws from the perspective of *constructivism*, where *"truth and meaning do not exist in some external world, but are created by the subject's interactions with the world"* (Gray, 2014, p. 20). The constructivism perspective is also related to the *Interactive Experience Model* (IEM) that Falk and Dierking (1992, pp. 1–7) introduced to outline the museum visit (fig. 8). The IEM concept is further perceived in this research as the "negotiation" between: the personal sphere, as suggested by Hooper-Greenhil (2007), Mason (2005) and Watson (2007); the physical object and its "power", as suggested by Dudley (2012); the narrative, experiential sphere, as a powerful process in the creation of meaning (Bruner, 1986, pp. 11–13).

More precisely, the above described negotiation works as the "vehicle" to understand how people perceive replicas. The results of the research are explained through a descriptive, mode (textual and descriptive statistics) and a conceptual model is introduced to map all parameters with respect to the production, perception and meaning-making process around replicas. The choice to conceptualise the results of the research is connected to its interdisciplinary character, which imposes a flexible and open approach that is inclined towards the *interpretivist* perspective while employing *conceptual* models to facilitate and "translate" the results of the research for both the information technology (IT) and CH sector. Therefore, *conceptual modelling* emphasises both the *semantics* of replicas, in order to discover how they convey meaning, and their *pragmatics*, so as to depict the importance of the context or situation for which the replica has been produced and used. Such conceptual model has the potential to inform future IT systems to design digitally fabricated artefacts and could also constitute a considerable set of recommendations for initiatives related to standards with respect to the production of digitally fabricated replicas in the CH sector[25].

With this stance in mind, it becomes clear that the research builds on theories and related work that reside -amongst others- in the fields of museum and visitor studies, perception theories, product design and IT. These theories also constitute some of the key theoretical foundations of cultural informatics and digital humanities as domains of interdisciplinary research and practice.

3.3 Research reasoning and approach

The research began by gathering information from multiple sources (literature review, observation of audiences, informal discussions with stakeholders and visitors) to form a starting point about the properties of the replicas and audience's requirements for further investigation. Several outreach, educational events at the Brighton Museum, workshops for audience groups and professionals along with sessions for pupils and students about 3D imaging and printing, where the researcher participated, constituted valuable opportunities to discuss about 3D printed artefacts and discover what people think and ask about them. By

[25] A similar example is the London Charter which proposes a set of principles for the use of computer-based visualisations in the CH sector (The London Charter, 2009).

using this input and conducting extensive literature review, a structure of properties, a *hypothesis*[26], for the subject of investigation was composed. As Creswell states (2009, p. 64), it is possible for qualitative study to begin not from pure raw data, but from a prior conceptual structure composed *inductively*[27] of theory and method, that provides the starting point for research. This hypothesis is presented in Chapter 4 and is examined primarily *deductively*[28] with target groups under specific contexts, while allowing other themes to emerge. The structure is finally re-examined in the last chapter of this thesis (see 8.4), in order to see whether any adaptations are necessary (fig. 9).

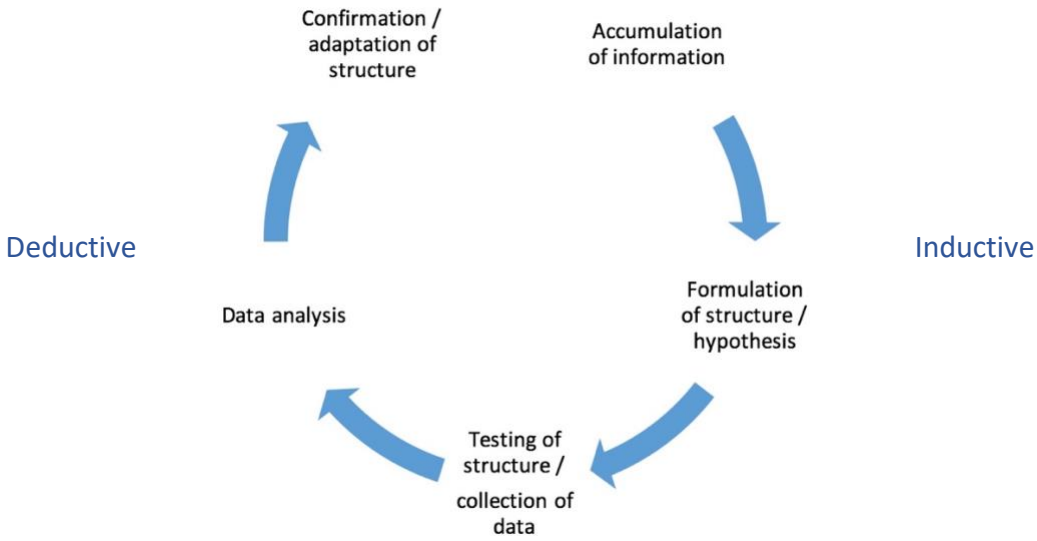


Figure 9: Research reasoning.

In order to examine replicas and how people perceive them within interpretative scenarios, the research deploys the approach of case studies. Case studies involve analysis of real-life

[26] Hypothesis is perceived in the context of this study as a theoretical and empirical framework, a "sufficient blueprint for the study" as Yin (2009, p. 36) calls it, that facilitates research in order to create a procedural set of relations and interactions to investigate. This "working hypothesis" does not aim to represent the ground truth, nor should it be perceived as a system of propositions between simple variables. On the opposite, it is rather a purpose and it stands as an adequate framework for interdisciplinary research that respects contextual parameters (social, individual and other), connects theory and practice and is re-examined towards the end of the project (Bertaux, 1981, pp. 34–37).

[27] The inductive reasoning does not intend to corroborate a theory or concept. Instead, it often starts by studying theory and collecting data that will then define possible patterns or relations between the units of investigation (Gray, 2014, pp. 17–18).

[28] This kind of reasoning is close to a hypothesis adaptation process. The deductive approach involves the collection of evidence to then confirm, reject or modify a concept with measurable operational indicators (Gray, 2014, pp. 16–17).

subjects and situations. They enable researchers to comprehend ideas in-depth by investigating contemporary phenomena, resolving facts and concluding to certain views. The case study approach calls for the researcher to make conscious and deliberate choices from amongst a number of events, people, organisations in order to study phenomenona. The case study approach has been chosen as (Denscombe, 2007, pp. 35–47; Yin, 2009, pp. 2–23):

- it deals with operational links that need to be traced and explored (i.e. the properties of replicas and their relation to audiences and experiences);
- it provides an opportunity to approach a specific aspect of a problem and investigate it in depth while being procedural (i.e. the way that replicas work in experiences);
- it can deal with the subtleties and intricacies of a situation while emphasising relations and processes (i.e. the complexity of experiential frameworks);
- it is not restrictive to the use of methods, evidence and data, which might become necessary for interdisciplinary research (i.e. use of quantitative and qualitative data).

Of course, when using case studies *generalisation* of the whole spectrum of results might not be possible. Some of the key issues are firstly related to the *representativeness of the case/role of context*. In this research, case studies investigate a group of attributes of digitally fabricated artefacts with specific target audiences within specific contexts. Even though it might seem a restricted field of doing "sampling" research, it can still contribute towards understanding fabricated artefacts. The reason is that the selection of cases (and their context) has been done so as to maximise what can be learned and contribute towards the generalisation of a *theoretical proposition* about replicas (Tellis, 1997; Yin, 2009, p. 15). Thus, a systematic and comprehensive list of the properties of replicas is set for the first time and, along with the recommendations presented in 8.3, has the potential to support CH professionals when making decisions about the production and integration of replicas in heritage experiences.

A second consideration concerns the *generalisation of results*, which is also related to the representativeness of the case. For the purposes of this research, case studies are perceived as opportunities to test replicas and propose ways to produce and use them to satisfy requirements of different audiences. Part of this research is also dedicated to the examination

of results in order to identify the extent to which some aspects apply to all or part of the case studies (see 8.2 and 8.5). Nevertheless, we must not ignore the fact that such a choice belongs ultimately to the reader and user of the research, who will decide how far the findings have implications across other types of replicas, audiences and contexts.

A third issue is the representativeness with respect to the selection of audiences, which is called *audience dependent sampling*. Findings from testing fabricated artefacts with specific groups can enhance or modify the theoretical proposition about replicas. The results, though, can be further reused, expanded and altered so as to satisfy the requirements of different audience groups and "feed" CH practice and research in a field which is evolving fast and is expected to change our manufacturing processes and lives.

Lastly, another consideration is the *artefact dependent sampling*. As a small number of objects has been chosen for the case studies (one per each study), one concern could be related to the representativeness of the artefacts. The object type is important; however, the essential contribution is the introduction of the framework (see Chapter 4) that can support decisions for the creation and use of replicas in CH communication. This framework has been designed to cover as many types of artefacts as possible and might not include other kinds of objects (e.g. large-scale monuments or sites). In any case, it can certainly be expanded to further include other types or representations of objects in the form of replicas.

3.4 Research design

The design for the research constitutes as Yin states (2009, p. 26): *"the logical sequence that connects the empirical data to a study's initial research questions"*. The research design cannot only be perceived as a work plan. Its scope is to define: the research questions, the research propositions, the units of analysis, the logic linking data to propositions and the criteria for the interpretation of findings (Yin, 2009, p. 27). The research design is presented in the following sections.

3.4.1 Research questions

The research questions (RQ) are:

RQ1: What are the possible intrinsic and extrinsic properties of digitally fabricated artefacts?

RQ2: In which ways do the properties of digitally fabricated artefacts address the requirements of different audience groups?

RQ3: How do digitally fabricated artefacts work in CH experiences for different audience groups?

RQ4: How can we describe digitally fabricated artefacts in a conceptual model that both documents them and decodes their role within cultural heritage experiences?

3.4.2 Scope and research propositions

The quality of the investigation, the evaluation and the research rely fundamentally on the ability to collect and analyse data. After defining the research questions, appropriate methods need to be selected as well as appropriate data analysis techniques and interpretation of findings. The rationale for the design of the case studies and the selection of the appropriate data collection methods to respond to the research questions are presented in the following sections. All proposed methods emerge from the fields of product design, visitor studies, museology, perception theories and IT.

The purpose and scope of this study is to investigate what the properties of the replicas are and to explore how they work in the interpretation process, so as to inform future decisions of professionals and other stakeholders who will produce a replica to deploy it for audience engagement. Therefore, the research questions define the investigation, set boundaries and up to a level provide directions for the means to be used.

The propositions for this research rely on a study that starts as *exploratory*[29] and later becomes *explanatory*[30] in terms of identifying possible connections between replicas and the CH experience. In more detail, the research seeks to understand what the properties of replicas are, how these relate to specific audience groups and then how do they work in the context of CH experiences to support interpretation, learning and enjoyment in non-formal

[29] Exploratory is the research that investigates a subject or situation in detail. With the use of exploratory research, we can gain familiarity with a phenomenon and acquire insight in order to develop a hypothesis. This type of research design does not intend to offer final solutions but alternative options for a solution.

[30] Explanatory is the research that connects ideas to understand and explain phenomena. It should be pointed out though that causality is difficult to be investigated particularly when discussing about humans, given the many unknown parameters and cognitive, emotional or knowledge "burden" that one carries along in every exhibition or CH setting. All these "burdens" affect people's interpretation and of course their perception about CH artefacts and events. Thus, it would be wise to focus not on the causality but on the contribution an experience has made to the quality of someone's life.

learning settings. This is the rationale for the research and this logic determines accordingly the details of the research design.

3.4.3 Units of analysis

An important element for all research and especially for case study research is the determination of the units of analysis. The way that the units of analysis are perceived is a matter of decision which is driven by the research questions, the scope of the study and ultimately on the epistemological stance and the recognition of the contextual parameters in research. In this research, the ultimate subject matter is a phenomenon. Thus, the units of analysis belong to the triptych of the CH experience: the *personal*, the *social* and the *physical* context. Special emphasis, though, is given to the digitally fabricated artefact (which is part of the physical context), and its properties.

3.4.4 Research questions and sources of evidence

RQ1: What are the possible intrinsic and extrinsic properties of digitally fabricated artefacts?

The first exploratory research question addresses the need to construct a theoretical proposition, where the digitally fabricated artefacts can be placed, documented, studied and evaluated (the framework proposed in Chapter 4).

The sources of evidence responding to this question and forming the research hypothesis are:

- Preliminary observation in CH events: Several preliminary unstructured observations and participatory observations took place during a variety of events at the BMAG, schools and other outreach activities. The purpose was to familiarise with the subject of investigation and note a set of modalities that emerged naturally from looking at people interacting with replicas.
- Discussions, semi-structured and unstructured interviews: These were mostly non-formal discussions with various stakeholders coming either from a CH professional background, such as curators, educators, designers, communication officers or from a research background exploring the potential of replicas through interdisciplinary investigation. Other discussions took place (along with the observations) at events where replicas where available to interact with for the members of the public.

- Document analysis: Extensive bibliographical research revealed how other disciplines have dealt with the topic of properties of materials or products and how do people perceive them. Several decisions were made at this stage to critically study theory and deploy the propositions that are meaningful for the purposes of this research, in order to synthesise a specific framework that applies to digitally fabricated artefacts.

RQ2: In which ways do the properties of digitally fabricated artefacts address the requirements of different audience groups?

RQ2 is also responded by using an exploratory design in order to find out what is happening within a given context. To rephrase the question, here the aim is to discover *"What do people like or dislike about a replica that has been provided?"*. In this way the requirements around the replicas' properties can be gathered (visitor preferences translated into requirements). Hence, RQ2 seeks to detail what people think about the properties of a replica according to their opinions within given contexts. The exploratory approach is useful in this sense for conducting situation analyses, studying phenomena and benefiting from drawing on both qualitative and quantitative methods. The process requires recording and analysing the impression about the properties of a replica. Second level questions seek to discover how people would like the replica to be, in case they wanted some of its features to change.

It should be understood though that the nature of the interdisciplinary research imposed a flexible and pragmatic approach towards this question, that has been approached in a *measurable* way. Apart from providing specific evidence, the reason is also related to the fact that a large part of the replica properties can be controlled, manipulated and measured to effectively engage audiences. This stance, evidently, seeks to quantify some aspects of the research (i.e. RQ2) and could be perceived as moving towards a *post-positivist*[31] approach which intends to quantify while *pragmatically* accepting that social phenomena, such as the

[31] In cultural heritage studies, the post-positivist approach recognises that meaning making cannot be perceived as an objective process and is human experience dependent. Post-positivism embraces the aspects of data collection, measurement and analysis but rather on a basis of conjectural knowledge, which is not built upon absolutely secure foundations (Lindauer, 2005). Hence, remains open to several interpretations.

CH visit end experience, do not exist outside of human interaction and multi-level negotiation (e.g. social, personal) (Lindauer, 2005).

The evidence responding to RQ2 has been collected through:

- Observation: Observation records how people express themselves when touching a replica, what surprises participants, what do they pay attention to and other aspects of the experience of the replica itself.
- Questionnaires (post-observation): Questionnaires investigate whether people are satisfied with the properties of replicas (e.g. colour, shape) as well as user experience aspects, plus information about the participants of the study.

RQ3: How do digitally fabricated artefacts work in CH experiences for different audience groups?

RQ3 comprises an explanatory investigation trying to illuminate the ways in which replicas work in experiences for target audiences. Through this question, the research seeks to understand how people create meaning within contexts. Thus, the evaluation is concerned with topics such as learning, inspiration, creativity, enjoyment, meaning making, emotions, attitudes and other that constitute the "output" of experiencing an exhibit with the use of a replica.

The data collection methods providing evidence for this RQ are:

- Interviews: These are individual interviews with semi-structured topic guides collecting qualitative data. Interviews elicit information and opinions, beliefs, understanding, values with respect to the use of replicas in context-dependent situations.
- Focus groups: Focus group discussions using semi-structured topic guides allow to record what a group thinks about several issues and reveals possible variations, different opinions and ideas.
- Questionnaires (post-observation): Questionnaires include open-ended questions with respect to the overall impression of the experiences.
- Artefacts and graffiti wall cards: These methods were used to gather evidence from children about the experience of the puzzle-pot replica, following a more open and flexible approach to the matter of investigation. Artefacts (see section 3.4.5.6 on artefacts as data collection methods) constitute the product of craft that the children

decorated in the third case study. These data are complemented by textual information in the type of a graffiti wall card, identifying further aspects of the experience which are not part of a semi-predetermined type of questions. Hence, graffiti wall cards allow data to emerge and are considered a responsive method, which respects people's time and pace (Adams et al., 2008).

The main topics of discussion to guide interviews and focus groups are related to skills, attitudes, behaviours, interests and knowledge/awareness. It should be highlighted that the above set of topics encompasses the traditional *user experience* (UX) aspects with regards to utility, aesthetics, identification, stimulation and value (see also 4.4.2). Thus, most of the UX aspects refer directly or indirectly to the expression/perception of the experience as analysed in frameworks, such as the *Inspiring Learning for All framework* proposing the *Generic Learning Outcomes* (Museums Libraries and Archives Council UK, 2008), as well as other evaluation models (see section 2.8).

Nevertheless, the traditional notion of *usability* (a fundamental part of UX) and the methods that this is usually measured in terms of tasks, completion time and number of errors (International Organisation for Standardization, 1998) were not considered as the most appropriate for this research. Such measurements might not provide a holistic insight to explain why a system is good or bad or enjoyable. This problem draws upon the challenges in the fields of evaluation of ubiquitous computing and tangible interaction; i.e. moving away from a structured and task/work related experience, embracing new forms of human activity, prioritising "real" or "authentic" use of a system in "living laboratories" (Dix et al., 2004, pp. 731–733). It also reflects the methodological movement towards a rather holistic way to examine and evaluate ubiquitous or multi-modal systems that do not just aim to be effective or efficient, but also fun, pleasurable and able to contribute to a unique experience. For this reason and as the main subject of this research is the highly context-dependent "living experience" that is enriched with the use or a replica, a more qualitative approach has been adopted. This approach does not ignore usability issues, but it mainly attempts to understand the experience and its relation to interactive systems (when the replicas are smart) in qualitative ways and in terms of emotions, knowledge, attitudes and so on (Cairns and Cox, 2008; Dix et al., 2004, pp. 731–733; Lazar et al., 2017, pp. 439–441). More information related to usability and UX can be found in section 4.4.2.

RQ4: How can we describe digitally fabricated artefacts in a conceptual model that both documents them and decodes their role within cultural heritage experiences?

This conceptual model is built upon the findings of RQ1 in order to document digitally fabricated artefacts and provide a framework which can be expanded and used in the CH and IT sector (see Chapter 4). The framework is re-examined in the last chapter of this thesis, based on the findings from the case studies.

3.4.5 Data collection methods

3.4.5.1 Observations

The aim of observations, in the context of this research, was to record what visitors *said and did* directly instead of what *they said they did*. Semi-structured observations were deployed to reveal modalities regarding the use of replica, as well as behaviour patterns of the participants. Choosing the semi-structured observation method, has been decided as the most appropriate way to record specific information about the personal, social and physical aspect of the visit or interaction with a replica while providing space for comments that did not necessarily belong to any of the predefined sections.

In more detail, observation sheets or protocols were designed to include general demographic information about the visitor and information about the social context of the experience. Some of the recorded data concerned the composition of the visit, the members of a visiting group, who might be in charge and the communications that took place during the experience. As for the physical context, the atmosphere of the setting was described. Then, information about the attractiveness of the replica, the trajectories of the visitors, their attention to specific features of a replica, the original display and other content as well as usability comments were added. All observation sheets provided some space to take notes freely not only about the participants' behaviour but also about the researcher's thoughts and opinions as they emerged from the observational process. As Diamond et al. suggest (2016, p. 60), this kind of notes also constitute valuable field data. All observational data were complemented with questionnaires in order to record the demographic information about the participants.

For the case study with visually impaired visitors, a more flexible approach was adopted that could be perceived as a semi-structured observation allowing some interactions with the

participants in case they asked a question or requested some information or needed some help. This kind of communication could be considered as moving towards *participant observation*, where the observer does not only adopt a passive behaviour (Yin, 2009, pp. 111–113), and was deemed necessary in order to respect participants' needs and accommodate possible requests.

3.4.5.2 Questionnaires

Questionnaires or surveys can facilitate data collection in terms of reaching a large number of people, gathering data rather quickly in an anonymous and possibly more honest way (Nelson and Cohn, 2015). Data deriving from questionnaires about the properties of replicas were recorded, analysed and interpreted in quantifiable manners. The type of questions that questionnaires included were close ended, gathering nominal and ordinal data, as well as open-ended detailing the impressions of the experience with the replicas. All questionnaires were divided into sections to collect evidence about:

- the background of participants
- demographic information
- object and application evaluation (for smart replicas) on a 5-point satisfaction rating scale
- the impression of the experience by asking people to comment on the replicas and their features (open-ended questions).

The guidelines and questions suggested in Diamond et al. (2016, pp. 75–79) were particularly useful during the questionnaire design. Personal, demographic questions were placed at the end of the survey and all questions were phrased as clearly as possible. It should also be noted that questionnaires were collected in combination with observations and interviews to create a more reliable "sequence of data" that would also facilitate analysis.

3.4.5.3 Interviews

Semi-structured interviews were used to record information about the experience that participants had with the replicas and accompanying interpretative material, such as a mobile application with audio content and other resources. All interviews were audio-recorded, after gaining approval by the participants, in order to maintain an accurate account of people's statements. Appropriate transcription software was later used to transcribe all interviews and use their content for coding, data analysis and display.

Interviews are powerful data collection methods in case study research, as they can reveal detailed information and provide an understanding on how the CH experience is perceived by audiences. At the same time, interviews are open to clarifications, repeated questions and in-depth examination of a subject or behaviour (Nelson and Cohn, 2015). The semi-structured approach has been chosen for this research to focus on audiences' perception of CH experiences by using a set of questions, while allowing several stories and ideas to emerge. Such an approach is also related to the *authenticity* idea as deployed in the research (see 3.5 for the relation between authenticity and reliability in research).

The semi-structured interview protocol included questions around the perception and expression of the experience, such as general impression queries and then questions about the topics of skills, attitudes, behaviours, interests and knowledge. The *Generic Learning Outcomes* question bank released by the *Arts Council* (2014c), as part of the *Inspiring Learning for All* initiative, provided lots of input for the interviews. Lastly, it should be pointed out that interview data were complemented with questionnaires (and observations) in order to keep track of the demographic data of participants.

3.4.5.4 Focus groups

Focus group discussion was deployed for the pilot of the first case study at the Booth Museum with visually impaired visitors. Focus groups are considered as a valuable source of information to reflect on CH audience requirements, reactions to new experiences and specific applications (Nelson and Cohn, 2015).

Selecting this method was mostly related to contextual parameters, as the pilot study was part of a set of activities on that day at the Booth Museum (see section 5.4.2 for more details). The limited available time with each participant, the presence of museum officers and volunteers or helpers who could not be ignored, as well as the structure of the previous activities that took place at the museum (i.e. 3D printing session) with the whole group implied this choice as the most appropriate. The focus-group, semi-structured discussion was a researcher-facilitated discussion where participants were asked about the experience with the replica and complementary interpretative material. Further questions aimed to explore and record the outcome of the experience with respect to skills, attitudes, behaviours, interests and knowledge, as suggested by the interview protocols.

3.4.5.5 Video recordings

Video recordings were employed as a method to facilitate observations for the case study with visually impaired and blind people, as participants were only available for limited time during their busy schedule and activities. The researcher asked for approval to record before turning on the camera. All video data were later transcribed into the semi-structured observation protocol which included sections about the social, personal and physical context of the experience and required information about the interaction with the replica and application. Even though video recordings have not been utilised a lot in visitor studies, they have proved valuable sources for the purposes of the research. Videos are considered as a precise recording tool which permits to perform detailed observations, repeat viewing and pay attention to things which were not obvious in the first instance (Damala et al., 2016).

3.4.5.6 Artefacts and graffiti wall cards

Artefacts, such as youth-created products, works of art and other types of physical evidence can be considered as valuable sources of information (Nelson and Cohn, 2015; Yin, 2009, p. 113). Artefact data were used for the third case study to record children's feedback about the use of the puzzle-pot replica at the new Archaeological Gallery of the BMAG. In more detail, the activity was proposed to children while adult members of their family responded to interview questions and filled in questionnaires. Children were provided with materials to decorate a small puzzle piece, similar to a piece of the replica they had played with and write their opinion about it on a card.

To a certain point, this method can be considered as a hybrid approach between drawings, which have been used to gather data from families in museums (Moussouri, 1997; Studart, 2000) and graffiti wall cards[32], since there is some textual explanation as well. Similar methods have been used in IT research in the heritage context to elicit information on museum interactives by deploying drawings as prompts for further discussion with children (Nicol and Hornecker, 2012). The method proposed in this thesis has been piloted during outreach

[32] Graffiti walls are an alternative form of comments' books and can have the form of small notes, cards and other (Foster, 2008). A card with a simple design and a question where children can write their idea about the artefact they decorated is a form of graffiti wall card.

events where the researcher participated (without collecting data) and proved an engaging activity for children and young audiences. Some examples of these artefacts and cards can be found in fig. 10.

Figure 10: Artefacts created by children and teenagers on cards.

3.4.6 Multiple-case or collective design

A principal choice for the case study design is whether this constitutes a single-case or multiple-case research. The *multiple-case* or *collective embedded* approach was chosen for the research, as it can provide richer, in-depth and more robust evidence about the use of replicas in the CH experience. The purpose here was to find out whether there are commonalities or differences between case studies. Thus, the topic of research, the CH experience with the use of replicas, remained the same for each case study. However, each individual case study consists a complete study, whose elements are analysed and examined separately to draw conclusions.

At a second stage, by examining all case studies, convergent or divergent information evidences the extent to which findings are applicable to other groups or purposes. It must be pointed out though that the goal in doing such examination is not the *statistical* (even though descriptive statistics are used within each case study) generalisation but the *analytical* one (generalisation of the theoretical proposition). This type of analysis can be characterised as *embedded* (Creswell, 2007, p. 75).

3.4.7 Saturation and sample size

The subjects of investigation for this research consist of the digitally fabricated artefacts and the audience that interacts with them within contextual frameworks including the physical, the social and the personal aspect of the visit. The sample for the research comprises different target groups of CH visitors who experience the fabricated artefacts.

The sample size for qualitative research depends on a variety of factors or as Patton explicitly states: *"There are no rules for sample size in qualitative inquiry"* (2002, p. 244). Nonetheless, the number of participants and data should assure that all or most of the perceptions and voices are heard. At the same time too much data need to be avoided to prevent information from being repetitive and superfluous (Mason, 2010). Therefore, the sample size ultimately depends on the project design and its aims. In more detail, the variety of factors that define the number of participants for a study are related to (Morse, 2000, 2015; Patton, 2002, p. 228; Ritchie et al., 2003):

- the scope of the research;
- the nature of the topic/subject of research;
- the quality of data and the amount of data collected from each person;
- the design of the research;
- the use of shadowed data (i.e. reporting on other people's experiences);
- the ability of the investigator to interpret data;
- the number of selection criteria;
- the heterogeneity of the participants;
- the types of collection methods;
- the available resources (time, energy, availability of participants).

While taking into consideration the above, the most crucial indication and practical advice is to seek *saturation* before stopping any data collection (Morse, 2015). Saturation happens when the addition of participants to a study does not result in additional layers of information. As Charmaz (2006, p. 114) suggests, saturation will occur early if the phenomenon under investigation has "modest claims". The research design and more specifically the use of multiple methods to investigate the subject matter can also influence the saturation point. Therefore, gathering evidence with a variety of methods to explore how defined groups of people perceive and experience the proposed replicas, can be considered as a good effort to achieve saturation faster.

The actual approach with respect to sample size that was deployed for this research lies between literature suggestions (guidelines, rather than rigid rules), the quest for saturation when doing the actual data collection (e.g. repetition of comments/themes) and availability

of resources (budget, time etc). Some of the suggestions that can be found in literature about the number of participants in phenomenological and qualitative research are:

- Morse (1994, p. add page) suggests having at least six (6) participants;
- Bertaux (1981, p. 37) states that by the fifteenth (15th) story most patterns emerge and by the 25th researchers have all needed data;
- Charmaz (2006, p. 114) proposes that twenty-five (25) interviews suffice for smaller projects.

Diamond et al. suggest (2016, p. 45), less participants are generally needed for qualitative research than in quantitative studies to reach saturation. Another interesting comment that can be found in literature is what Guest (2006) noticed. Based on his findings, saturation occurs only after six (6) interviews when the level of homogeneity is high and is definitely evident when the number of interviews reaches twelve (12). This implies that multiples of six (6) or twelve (12) could work better when conducting interviews instead of ten (10) which is the most widespread practice in academic research (Boddy, 2016; Mason, 2010) .

In bibliography, there are not many suggestions as for the required number of focus groups either. In market research, the proposition for the number of participants of focus groups lies between ten (10) to twelve (12). For non-commercial research, though, this can be considered too high and non-achievable. Hence, a group of five (5) to eight (8) participants can work well and cover a good number of topics after a few repetitions. Based on Guest's (2016) research on focus groups, 80% of themes' saturation has occurred after the realisation of two to three (2-3) focus groups with relatively homogeneous population and 90% saturation of themes can be achieved after conducting three to six (3-6) focus group discussions.

In literature, there are no concrete numbers regarding observations either. The length of time for an observation and the number of observations that are needed depends on contextual parameters and the purpose of the study. Respectively, fieldwork should last enough to respond to the research questions and observations can be combined with other data. In any case, saturation -and hence triangulation- of findings occurs with the addition of further data collection methods.

Ultimately, this research "borrowed" suggestions about the number of participants from bibliography, without intending to choose sample sizes to then reflect to the entire pool of CH audiences. As the importance of context is recognised, a statistical logic to select sample

sizes would demand a countless number of variables that could not be perceived or examined. For the quantitative analysis, where generalisation is a concern, data illuminate different groups' opinions around replicas but do not intend to be generalisable for the whole population or even the same population trialling a different replica. As mentioned before, the goal is the development of a theoretical proposition rather than the generalisation of results *per se* (see also sections 3.3 and 3.4.6).

Taking into consideration all the above and most importantly noticing when saturation occurred, each case study had a sufficient number of participants to illuminate phenomena. In the first case study (visually impaired participants), there were twenty-five (25) participants and saturation occurred around the sixteenth (16^{th}) participant. The second case study (random adult visitors) had thirty-two (32) participants and saturation occurred around the eighteenth (18^{th}) participant. The third case study (families) had twenty-six (26) participants and saturation occurred around the fourteenth (14^{th}) interview session. After reaching saturation, data collection continued further to be able to corroborate findings with some additional participants.

3.4.8 Sampling strategy

The sample size of this research was determined by factors related to the *saturation* and *triangulation* of data (also presented in this chapter). Having stated that, the rationale for the *sampling strategy*, both for the qualitative and the quantitative data, has been shaped under the frame of collaboration with RPM and ranges between *convenience* and *stratified random* sampling. Convenience sampling is a practical method that utilises readily available resources, such as the visitors of a museum, the participants of a workshop and so on. Stratified random sampling on the other hand, groups participants according to meaningful characteristics, such as the existence of a disability, the presence of children in a group and adult visitors in a museum (e.g. not people with disability) (Fink, 1995, pp. 9–23). Therefore, the participants of this project have been selected based on some characteristics, but also constitute groups that are conveniently accessible through the collaboration with RPM and other organisations.

To minimise bias with respect to sampling strategies, the researcher has adopted an open attitude towards people's comments and reactions whether they were positive, negative or included unexpected information. To avoid recording only a limited number of opinions, which is the main concern about convenience sampling, the research includes -as much as

possible- participants: of a wide age range; with different types of visual impairment (visually impaired and blind); of different gender; people coming from the local area, further afield and from other countries. Data collection also happened in different days of the week both in the morning and in the afternoon. In all cases, the researcher tried to make people feel comfortable with all procedures, while following the pace of participants and always seeking for approval to use the collected data for the research purposes.

3.4.9 Selection of audiences

The selection of audiences for this research has been based on the idea of *target audiences* (see 2.6.3) as a flexible and open concept which: is one of the audience classification practices in the CH sector; can satisfy the purpose of the study; takes into consideration the available resources (time, amount of data, researchers); and the need to define an operational visitor framework.

By choosing target audiences it has been possible to design specific replicas and activities for user groups without compromising the exploratory and explanatory potential of the research. Motivational and interest aspects are also included in the data collection process about the individuals participating in the research, nonetheless they do not dominate the classification or selection of audiences, as in *Audience spectrum*, Falk's model of *visitor-identities* or *Culture segments* (see section 2.6 on visitor and audience research). For each one of the case studies a specific group has been selected. These are presented below.

Case study 1 - digitally fabricated relief of a "diorama" from the Booth Museum

The participants of this case study are visually impaired adults. These are people that might have acquired visual disability at birth (congenitally) or at a later stage due to trauma or declining vision. Blind and partially sighted visitors have been prioritised in target group selection, as they seem to be amongst the ones who can greatly benefit from the use of replicas, due to their tactile nature (just to name a few, see D'Agnano et al., 2015; Jafri et al., 2015; Neely and Rozner, 2015). In addition, research and official data (such as the *Overview of data in the Museums, Libraries and Archives Sector*, 2004) have shown that senior citizens are the fastest growing demographic group in developed countries and constitute a significant audience for museums (Matty, 2004; Reeve, 2009). This population often suffers from vision decline. One in five people over the age of seventy-five live with sight loss. In total, around two million people in the UK have sight loss that has a significant impact on their life.

Twenty-five thousand children under the age of sixteen are also visually impaired (Edwards, 2017).

As for the organisational context, recent data from the Booth Museum reveals that it had 29.459 visitors in the financial year 2015-2016, 25.272 in 2017-2018, and 27.096 in 2018-2019 (Royal Pavilion & Museums, 2018; Thomas et al., 2016; and information from the museum officers). The RPM managers include in their *Audience Development Plans*, the need to provide more means and attract larger numbers of disabled visitors to the Booth museum. In the RPM Audience Development Plan for the period 2015-2018 (while this research was taking place) they refer to the need *"to meet the needs of visitors with disabilities by improving access and interpretation, with the ambition that by 2017-2018 the proportion of disabled visitors (10% in 2014-2015) is higher than or equal to the local demographic of 16%"* (Royal Pavilion & Museums, 2016a). Based on information in the more recent Audience Development Plan for the years 2018-2022, 13% of the current Booth visitors identify themselves as having a disability (Royal Pavilion & Museums, 2018). In both reports (2016a, 2018), it is mentioned that Booth Museum needs to increase the facilitation of access for its disabled audiences in terms of infrastructure and by incorporating more interactive interpretative opportunities especially for visually impaired audiences. A first step to this goal, was the collaboration of the Booth with other CH organisations within the *Sensing Culture* project (Van Hesteren, 2016), which has enabled the initial approach to visually impaired and blind audiences for this case study. Thereafter, further participants from the *Blind Veterans* charity in Ovingdean, Brighton and the *Centre for the Education and Rehabilitation for the Blind* in Thessaloniki, Greece were recruited for the research.

Case study 2 - digitally fabricated pot by P. Picasso from the Brighton Museum and Art Gallery

The audience that was chosen for this case study are random adult visitors of the BMAG. The adults' group could include professionals or people with specialist knowledge, currently working or having past working experience in the broad heritage sector. The reason that data about past experience and specialist knowledge are included in this case study (and the research in general) is to see whether there are any tendencies with respect to people's requirements from replicas when they have a closer relationship with arts and heritage.

As for visitor numbers for the BMAG, 114.167 people visited the museum in the financial year 2015-2016, 100.619 in 2017-2018, and 90.820 in 2018-2019 (Royal Pavilion & Museums, 2018; and information from the museum officers). According to the Audience Spectrum segmentation (see section 2.6.6) for the years 2013-2015 (Royal Pavilion & Museums, 2016a, 2018), 27% of the Brighton Museum visitors were Experience Seekers, 15% were Metroculturals, 15% were Commuterland Culturebuffs and another 15% were Dormitory Dependables. On a demographic basis, most visitors of the museum belonged to the age group of 45-54 followed by the groups of 25-34, 35-55 and 55-64 (Thomas et al., 2016). All these people are adults who engage with the museum at different levels and constitute a target audience that is broad enough to potentially reveal tendencies as for the role of replicas in the CH experience. Lastly, it should be highlighted that the BMAG has recognised the use of IT as an opportunity to increase interactivity and engagement, enhancing visitor satisfaction with interesting interactives that facilitate interpretation of CH information (Royal Pavilion & Museums, 2016a, 2018).

Case study 3 - digitally fabricated Iron Age puzzle-pot from the New Archaeology Gallery of the Brighton Museum and Art Gallery

The target group for this case study consists of families with children between the age of six (6) and twelve (12) years old. This age frame is considered as appropriate in terms of integrating a type of interpretation that would be different for children of a younger or older age (Tilden, 1977, pp. 47–54). The selection of the group has also been agreed between the researcher and the museum officers who needed to incorporate hands-on activities in the New Archaeology Gallery of the BMAG, which specifically targets children audiences (fig. 11) and was inaugurated in January 2019.

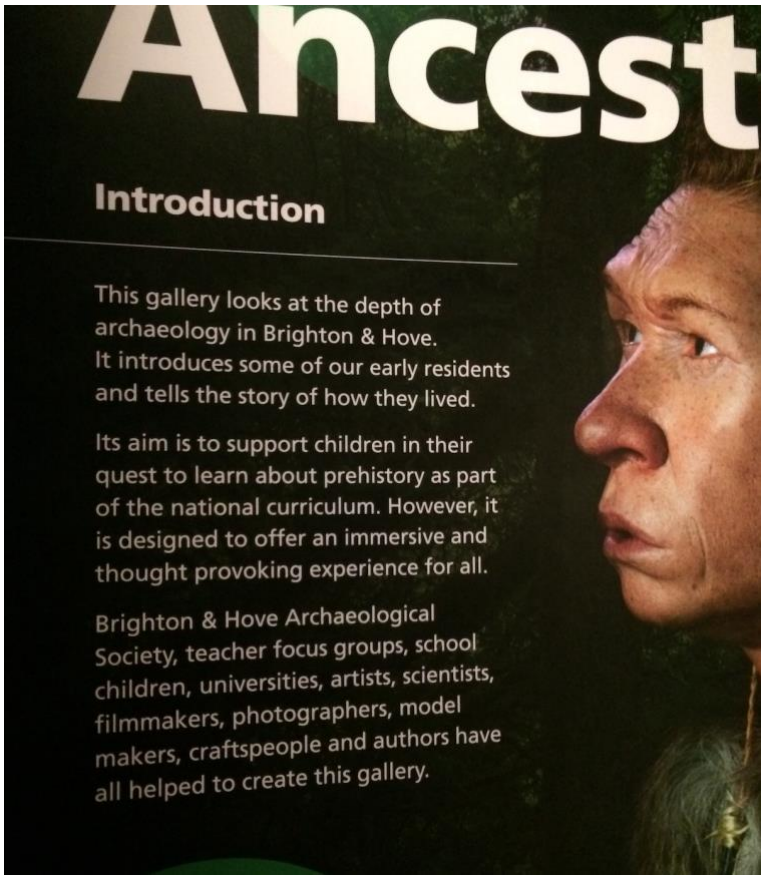


Figure 11: Introduction poster at the New Archaeology Gallery of the BMAG

In the frame of this case study, families are recognised as a group of adults and children with a variety of relationships between them including, parents, grandparents, step-parents, siblings friends and other (Hooper-Greenhill, 1994, p. 102). Families constitute an important part of a CH organisation's audience. Family programmes are popular with parents doing home-schooling, constitute a usual weekend destination or activity, are attractive to sponsors and can support children in learning (Reeve, 2009). Children appear to be amongst the people who can benefit the most from CH experiences with the deployment of replicas (Cabral and Justice, 2013; Miles et al., 2015; Neely and Rozner, 2015). Official numbers (in the *Overview of data in the Museums, Libraries and Archives Sector*, 2004) confirm that most people who visit a museum or CH institution in the UK belong to a family group or a school group. In 2018-2019, statistics reveal that there were 8.4 million child visits only to the sponsored museums and galleries in the UK (Department for Digital Media Culture and Sport, 2019a). According to the *Museums' Audience Report* from *The Audience Agency* (2018) and data coming from one hundred and five (105) UK museums, 35% of the audiences that attend a museum come in family groups. The BMAG also receives high numbers of families visiting its premises, as 15%

of its visitors belong to the Dormitory dependables and another 15% to the Trips and treats group (based on *Audience Spectrum* segmentation, see section 2.6.6) (Thomas et al., 2016). In 2016-2017, 3.064 visitors entered the museum on a family ticket and this number is certainly larger as it only includes visitors outside of Brighton and Hove (Royal Pavilion & Museums, 2018). Moreover, the museum officers have recognised the need to deploy technology in order to better engage visitors and form an attractive destination for families with children (Royal Pavilion & Museums, 2016a).

An important survey, realised in summer 2015 to record visitors' opinions on the potential to exhibit the archaeological collections of the museum (leading eventually to the opening of the New Archaeology Gallery in 2019), revealed that people would be interested in a permanent archaeological exhibition. Amongst people's comments there were references to families visiting such exhibition. The RPM officers recognised, as one of the most important elements of the report, the need to include hands-on children's activities (Royal Pavilion & Museums, 2015), in accordance with research identifying families' needs (Hooper-Greenhill, 1994, pp. 102–104). Today, the Archaeology Gallery at the museum constitutes one of the most promoted galleries especially for children and young visitors aiming to explore the local history of Brighton and Sussex.

3.4.10 Research ethics

One of the most important aspects of this research -and of every research dealing with human participants and beyond- are *ethical considerations*. The significance of conducting ethical research is major, as it ensures that the researcher follows certain standards in order to ensure the welfare and protection of participants. Such standards are based on principles related to avoiding physical and mental risks for participants; building trust while holding responsibility of the research; conducting investigation in an honest and truthful way; recognising boundaries and maintaining an -as much as possible- unbiased stance; respecting people's dignity, privacy, confidentiality, and self-determination at all instances (American Psychological Association, 2017).

In all case studies, the researcher got access to participants through the collaboration with RPM and other institutions. All participants took part in the research voluntarily and after providing informed consent for the use of their data. None of the participants got reimbursed. All case studies and data collection sessions were conducted in accordance with the UoB's

Guidance on issues in research ethics (University of Brighton, 2019), as well as the RPM's *Policy for the safeguarding of children and young people* (Royal Pavilion & Museums, 2016b) and *Equality and Inclusion statement for the Royal Pavilion & Museums* (Royal Pavilion & Museums, 2013). The research and all case studies were approved by the Tier 2 *Life, Health and Physical Sciences Cross-School Research Ethics Committee* (CREC) of the UoB.

3.4.11 Analysis of data and Interpretation of findings

The analysis of data is an important stage for every research project. This crucial step is what ultimately links data to results, allowing the interpretation of findings. The analysis of data in this research includes qualitative data and quantitative data analysis.

3.4.11.1 Qualitative data analysis

The analysis of qualitative data involves three phases (Diamond et al., 2016, pp. 94–98):

- Data reduction: This is the phase where data are examined through a process of selection, abstraction and simplification. While going through the data, the researcher decides about the important elements, the patterns that might arise and the relation of findings to the original research questions. Data reduction usually takes the form of coding, as comments and responses are classified under several themes.
- Data displays: The way that qualitative data are displayed is mostly through textual descriptions with the additional use of quotations to provide further evidence of the findings.
- Conclusion drawing and verification: The final step of the process is drawing conclusions based on the data analysis. Verification is related to the triangulation as well as other actions, such as re-examining interpretations with the participants of a research project.

Based on the description of the qualitative data analysis, it is easy to understand that *coding*[33] is of great importance when trying to classify data. Coding can be done by following one of the following strategies (Save The Children, 2014):

[33] Coding in qualitative research is the process by which data are categorised under a code label (a word or phrase) and then under further subthemes and themes. In this way, data can be easily retrieved for analysis.

- Framework analysis: This type of analysis examines findings with a pre-defined structure, which refers to the theoretical framework of the research. By adopting this approach, coding can be guided by the fixed pre-existing framework (deductive process).
- Thematic network analysis: Thematic network analysis considers and codes data, while allowing new perspectives to appear. By adopting this approach, codes can be added, modified or removed and thus change or extend the existing framework (inductive approach).
- Mixed approach: A mixture of the two methods to analyse data embraces both processes, providing a fertile ground for richer data analysis and results.

For the purposes of this research, a mixed approach has been deployed. Hence the proposed framework (in Chapter 4) provides a certain set of themes to investigate (primarily deductive approach). Nonetheless, interpretation is open to additional findings through inductive coding. Both processes have been facilitated by the qualitative analysis computer software *NVivo* from *QSR international*. The process of qualitative analysis is depicted in fig. 12 top; a screenshot of the analysis following the described process in NVivo is shown in fig. 12 bottom.

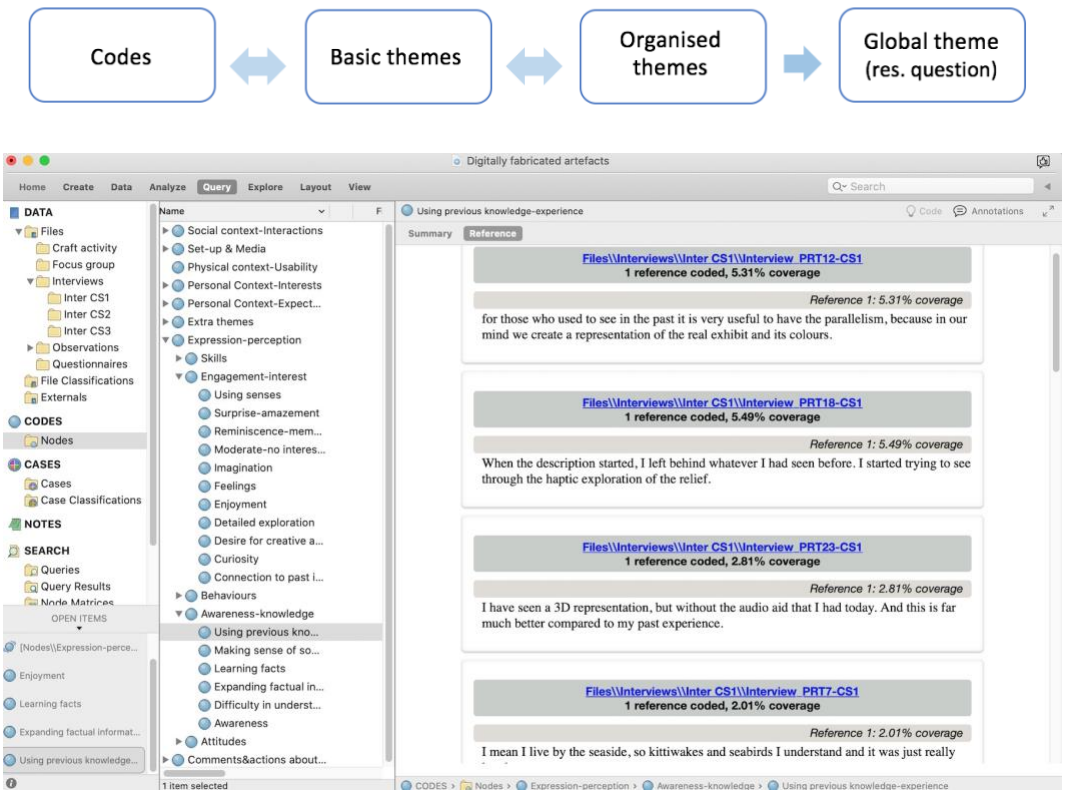


Figure 12: Data reduction-coding (top) and screenshot from the qualitative analysis software NVivo (bottom).

3.4.11.2 Quantitative data analysis

The analysis of quantitative data pertains to the questionnaires and information about the demographics of participants; their background; satisfaction measurement with respect to the properties of replicas; as well as the quantification of some qualitative data. For the analysis of data, which is mostly of ordinal and nominal nature, descriptive statistics are used. Categorical variables (ordinal, nominal data) are analysed in different ways than numerical variables. Categorical variables are analysed by presenting frequencies, proportions or percentages. Numerical variables by exploring mean, median and mode.

3.4.11.3 Overall analytic strategy

The analysis of both qualitative and quantitative data constitutes a conscious choice that aims to follow a meaningful yet operational framework in order to address the questions examined within the scope of this research. As Yin (2009, pp. 130–136) further explains, this deliberate choice falls under certain case study research *analytic strategies* which a. deploy both types of data to analyse events at a higher level (such as the perception of replicas by audiences as a notion that includes both quantitative and qualitative data analysis), and b. rely on the theoretical proposition of the research that has shaped the overall design of the study (see the *Replica Experience Framework* in Chapter 4). As for the analytic techniques that have been deployed, these emphasise *explanation building* (Yin, 2009, pp. 141–144) by analysing the qualitative and quantitative data in each of the separate case studies. The purpose is, in the first instance, to analyse phenomena (as in each case study) and to identify commonalities and differences through an a*cross-case examination* (Yin, 2009, pp. 156–160) as presented in Chapter 8.

3.5 Triangulation, authenticity and comprehensiveness

The deployment of qualitative and quantitative data collection methods under the case studies' methodology allows to use different types of evidence and confirm findings, while understanding better the subject matter (Jensen et al., 2011). Using multiple data collection methods refers to the process of *triangulation* to provide as much *reliability/authenticity* and *validity/comprehensiveness* as it is possible to the research. Here are some further explanations about the meaning of terms (Lindauer, 2005):

- **Reliability** deals with the means to collect data. Reliability is preserved when the data collection methods do not influence the behaviour or response of

participants. A reliable type of measurement (e.g. with an instrument) ideally offers consistent measurements regardless of the researcher who is in charge.

- **Authenticity** is concerned with the ability of the researcher (who is the instrument) to elicit information, while respecting participants' opinions, trying to be flexible and follow people's pace.
- **Validity** refers in the first instance to a valid relation between what is being measured and what is being asked (internal validity). It also refers to the representativeness of the participants in terms of being able to generalise the results of the research to a wider population (external).
- **Comprehensiveness** is about using multiple sources of evidence in order to form conclusions, without focusing on the aspect of generalisation.

Both the (positivist) criterion of *reliability* and the (interpretivist) criterion of *authenticity* are concerned with the means of data collection. The *authenticity* approach -that this research tried to follow- aims to adjust the rhythm and questions of a conversation to make interviewees feel comfortable and "allow" them to express themselves by using their own terms about expectations, ideas and experiences.

On the other hand, both *validity* and *comprehensiveness* articulate the relation between data and breadth of analysis. Yet, *comprehensiveness* seeks to understand what is happening based on a range of data sources in order to elicit a variety of perspectives. This range of opinions, ideas and expectations does not necessarily depict the social or demographic diversity in the sense of representative sampling and generalisability. Nevertheless, in order to respond to the need to create a framework for the production, introduction and evaluation of replicas in the CH experience, the analysis includes sufficient information from three separate case studies and from the across-case examination, allowing transferability of the *Replica Experience Framework* (see Chapter 4) or exemplification for other similar cases (Lindauer, 2005).

On the other hand, triangulation has been also deployed in the frame of the research as a technique to add depth and breadth to the study and contribute towards responding to the research questions in ways that comply and strengthen the authenticity and comprehensiveness of the research. According to Patton (2002, p. 556) there are four kinds

of triangulation that can contribute to the verification and corroboration of qualitative analysis. These are:

- Methods triangulation: For this type of triangulation, the consistency of findings is checked by using different data collection methods.
- Triangulation of sources: This type of triangulation controls the consistency of data sources within the same method.
- Analyst triangulation: This type refers to more than one analyst to control and analyse the findings.
- Theory/perspective triangulation: Theory triangulation uses different methods and theories to review data.

For the purposes of this research and in order to deploy an operational and feasible study framework, *methods triangulation* and *triangulation of sources* are the types of triangulation applied. The first type refers to the use of diverse data collection methods for the case studies, allowing different levels of investigation (e.g. observation, interviews, questionnaires). The second type offers the possibility to check data that have been collected using the same type of methods (e.g. qualitative data collection methods) but from different resources (e.g. visually impaired and blind participants, families, adult visitors). The goal is to respond to the research questions and understand whether methods and sources of data complement one another and significantly contribute to articulate the research findings.

Lastly, it should always be considered that methods "reconcile" and draw on each other's findings. Thus, open-ended questions have been included in quantitative methods -such as questionnaires- embracing the qualitative aspects of the research, while the opposite happens with the responses from qualitative interviews that have been be quantified.

3.6 Summary

This chapter presented the theoretical perspective, methodology framework, rationale and approach for the research. As an interdisciplinary project, the research draws on the relativist constructivist approach while deploying a pragmatic perspective, where post-positivist factors are used to measure part of the data and "translate" the results in the form of

concepts. In this way, knowledge can also be structured in terms that are useful and perceivable for the information technology (IT) domain and beyond[34].

The multiple case study design has been selected as the most appropriate methodology to address the research questions. The research employs both quantitative and qualitative methods to collect evidence. The analysis of the results is done within each case and then an across-case examination follows to discover convergent or divergent evidence that demonstrates the extent to which findings apply to different audience groups or purposes. Lastly, emphasis is given to the *authenticity* and *comprehensiveness* approaches for the verification of methods and results, which respect participants by placing them at the centre of the research, while gathering a range of data from different sources to elicit a variety of perspectives and achieve saturation.

The following chapter presents the *Replica Experience Framework (RXF)* which is the theoretical proposition that has guided the research throughout its development and completion.

[34] Replicas, being the products of an interdisciplinary effort, can only be considered if all perspectives are taken into consideration. Hence, conceptualisation can be useful for the IT sector, CH management processes, making activities and beyond.

4 Chapter 4: The Replica Experience Framework and the properties of digitally fabricated artefacts

4.1 Introduction

The purpose of this chapter is to study the properties of digitally fabricated artefacts and the ways that their contribution within interactive exhibit experiences can be perceived and described (related to objectives 1 and 4, see section 1.5).

The chapter introduces a concept map that presents the different components of the *replica experience* (related to objectives 4 and 5, see section 1.5). In the broader sense, the map defines the topics of investigation for the research with focus on replicas that exist in time, space, exhibition and are understood in different ways. This understanding depends not only on the physical characteristics of objects but on each individual visitor's previous knowledge, motivation, expectations and other contextual factors. The digitally fabricated replicas are placed and described within the ***Replica Experience Framework (RXF)***. A summary of the RXF concept map is presented in fig. 13, while the full extended version of the map can be found in Appendix A along with a reference table in the same appendix repeating the overall classification of the RXF and presenting its investigation topics. The RXF seeks to fulfil the aim of the research (as described in 1.5) and establish a framework to address the knowledge gap (as described in 1.3). Hence, the RXF defines a manageable list of properties documenting digitally fabricated replicas with respect to the CH experience (type, function and existence within experiences); identifying the main choices that professionals and researchers need to make when designing a replica; providing a structure to evaluate and understand people's perception of replicas in experiential frameworks; and setting out the topics of the investigation for this research (see also 8.4.1 for the contribution and value of the RXF).

The theoretical context that is deployed for the creation of this map resides in the fields of psychophysics, perception and cognitive psychology, visitor and museum evaluation, aesthetics, media and product design studies. Apart from the document review, the map takes into consideration information deriving from informal discussions with CH professionals and researchers during workshops, seminars, training and outreach activities. In addition, the map incorporates preliminary data and modalities that were noticed and recorded through

non-structured observations and discussions with members of the audience during museum events and programmes where the researcher contributed in several ways.

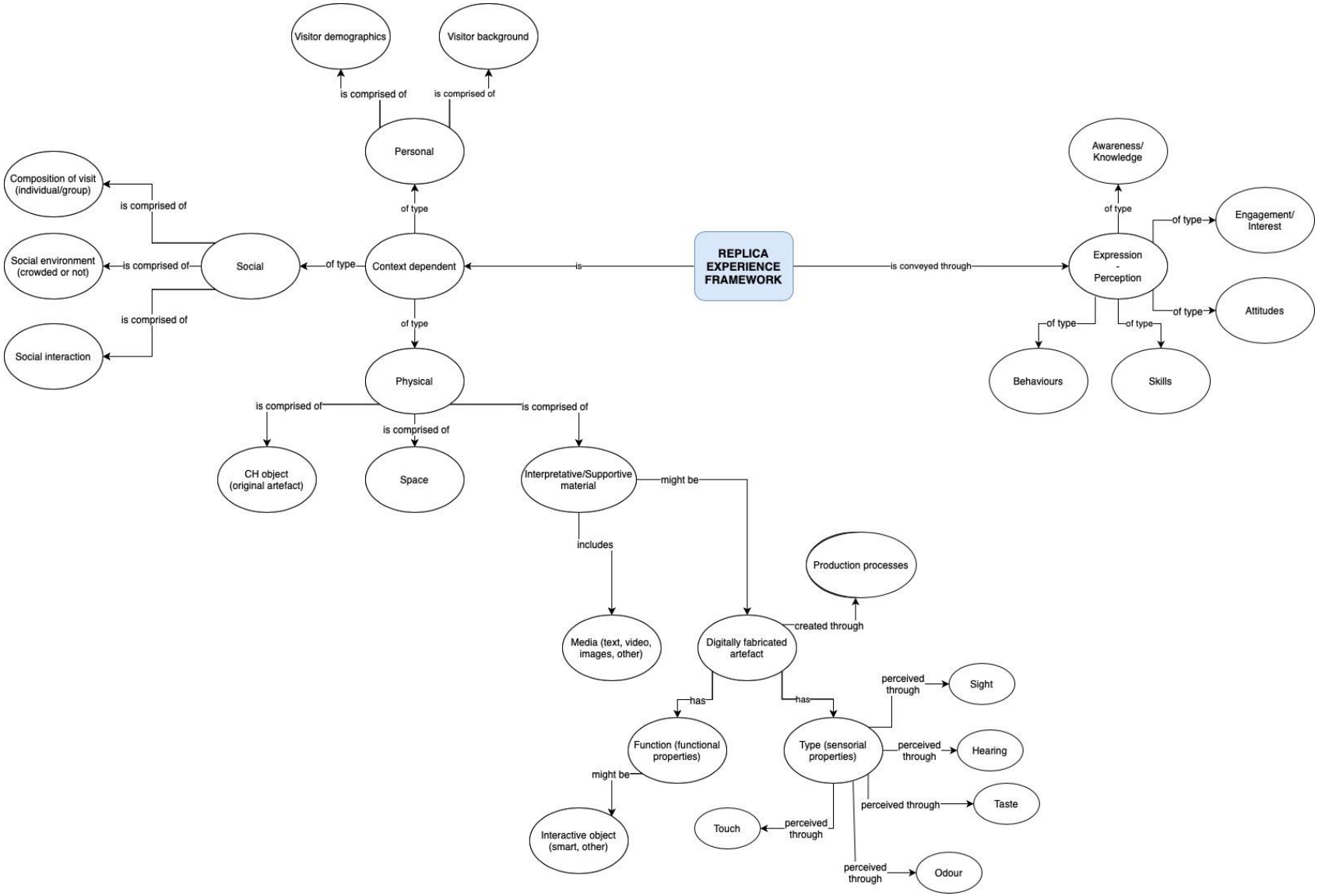


Figure 13: A summary of the concept map of the Replica Experience Framework (RXF).

4.2 Perception and relativist constructive approach of the RXF

The epistemological and ontological research of the aspects of the perceptual process is a matter of study since the ancient times. From philosophy to cognitive psychology and learning theories people have explored the issues around *perception* in multiple ways. Here, we discuss some of the areas of perception research and explain how the proposed model deploys them. The purpose is to define, through this process, the properties of replicas and the ways that an experience deploying digitally fabricated artefacts can be perceived, documented and analysed (objectives 1 and 4 of the research, see section 1.5). It should be noted, though, that there cannot exist sharp boundaries separating one aspect or field from the other and in many cases terms and meanings interconnect.

Sensory stimulation is one of the aspects that are usually examined first with respect to perception. *Sensation* is the process that provides the data to form hypotheses about the nature of the external world. This set of hypotheses form our perceptions. Sensation or sensory process is concerned with the first contact of the organism with the environment. Hence, a sensory study might look at the way people perceive sound, colour or brightness of an object (and other properties). On the other hand, *perception* (or *exteroperception* or *external/sensory* perception) is concerned with the conscious experience of objects and object relations. Thus, the study of perception looks at the ways people form a conscious representation of the outside world and the accuracy of this representation. Another term, *cognition*, is used to describe the study of memory, association, concept formation, language, problem solving and, according to many researchers, even attention, conscious representation and interpretation of stimuli. Thus, cognition sits somewhere between perception and learning, incorporating elements of both. Lastly, *information processing* emphasises the process leading to identification and interpretation of stimuli. Information processing tends to incorporate all phases as it includes the registration/sensory, the interpretation/perceptual and the memoric/cognitive phase (Coren et al., 1999, pp. 8–10).

In this research, the approach that is followed with regards to perception and cognition is rather a *constructive approach*, as the RXF model suggests. Constructive theories and/or intelligent perception theories with an orientation towards cognition argue that in addition to using information which reaches our organs and senses, humans also make use of previous knowledge, expectations and motivations (Coren et al., 1999, pp. 8–11, 252–253). This

argument also pertains to relativist/constructivist theories that Falk et al. (1998; 1992) deploy to investigate visitor learning which is affected by "visitor agendas".

Figure 14: Highest level of the concept map. The RXF is context depended and conveyed through the audience's expression.

The co-existence and interaction between the context of the RXF and the ways it is expressed and lived by the CH audiences is presented at the highest level of the concept map (fig. 14). Such a theoretical proposition not only acknowledges the synergy between prior knowledge and new experience, resulting in perception and information processing, but accepts the overall importance of the contextual parameters as well. To summarise, the above described principles reflect that stimuli: cannot be perceived in isolation; are represented in the proposed model; form the topics of investigation for the research in the following levels of the map.

4.3 The context of the RXF

Most of the theories investigating the different properties of materials or objects and the meanings that are associated with them within an experience agree on the importance of context. Context includes the social factors of a visit (e.g. group or individual visit), the space of an exhibition or other setting, the supportive material and all parameters that influence the ways that experience is conveyed. Audience's agendas or goals, standards, knowledge and likings affect and "filter" this situational whole at all times (Falk et al., 1998; Karana, 2010; Krippendorff and Butter, 2007). The *Interactive Museum Experience* (IME) model as introduced by Falk and Dierking (1992), called *Contextual Model of Learning* in the revised version of their book (Falk and Dierking, 2013), refers and analyses the common strands and the complexities that run through the museum experience and belong to the framework of the personal, physical and social (sociocultural) context.

Based on the scope of this research, it is meaningful and desirable to investigate how different audiences experience a digitally fabricated artefact. Hence, the contextual parameters of such experience must be taken into consideration, in order to identify the meanings that people weave around the fabricated objects. The RXF map encompasses *personal*, *social* and *physical*

contextual aspects. These are described in the following paragraphs along with the data that are recorded to document each one of them.

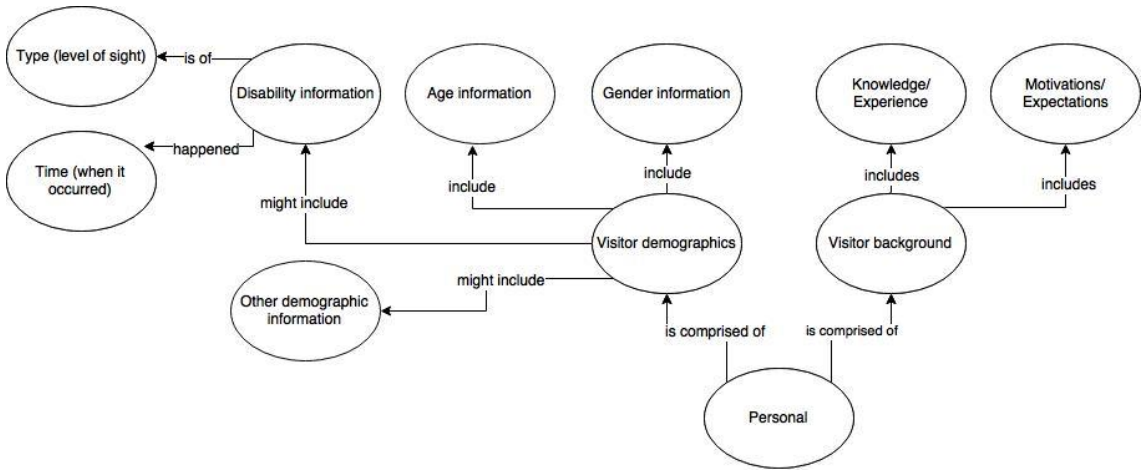


Figure 15: The personal context of the RXF.

The **personal context** (fig. 15) largely responds to the question about the type of people who visit the CH space or take part in the experience and consequently interact with the fabricated object. Data recording the personal context can help to understand audiences' behaviours and opinions. The information that can be collected around the personal context is vast in terms of describing age, gender, social and financial background, leisure-time decision making criteria, knowledge, motivations and more.

Demographic criteria are important and useful to provide information about the status of CH visitors (and non-visitors when data representing an audience are missing). Nonetheless another interest of this research -when dealing with the personal context- is also the "agenda" or the experiences that these audiences bring to the CH visit (as this might influence their perception of replicas). Hence, the information that has been recorded about the personal context concerns *visitor background*: people's *knowledge* and *previous experience*, i.e. knowledge on subject/content, various levels of experiencing CH objects, relevant professional background, previous visits; and people's *motivations and expectations*, i.e. what experiences do people seek, what interests them the most, what did they plan to do, what did they expect to find. This type of information determines a large part of the IME and the

RXF (Falk et al., 1998; Falk and Dierking, 1992, pp. 2, 20–37). *Demographic* data on the other hand include *gender, age*, *residence, ethnic background* and *disability* information[35].

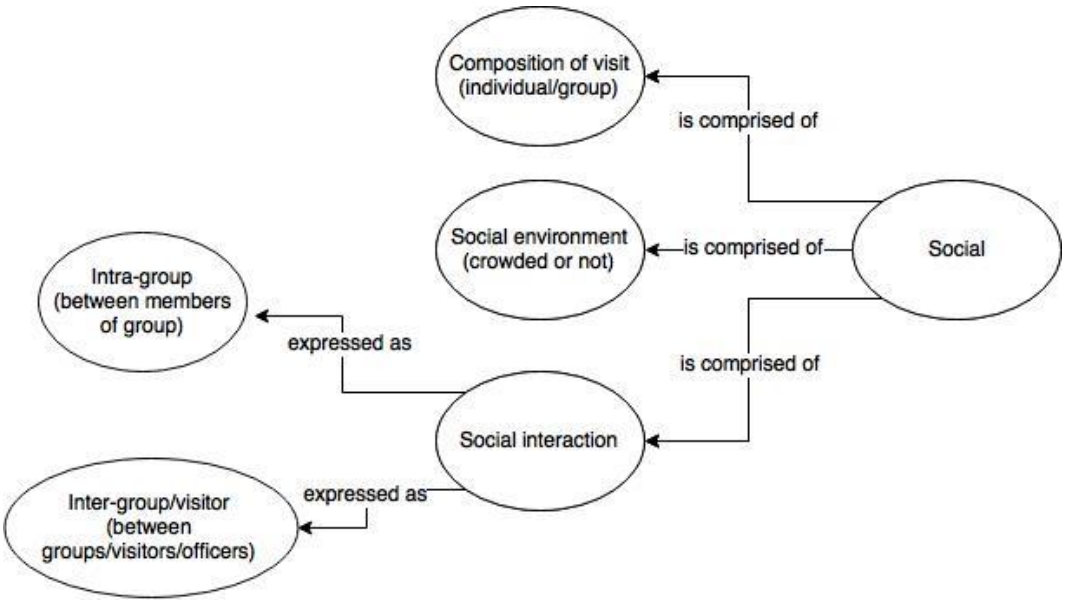


Figure 16: The social context of the RXF.

The **social context** (fig. 16) of the RXF connects visitors to other individuals (or not) and records the interactions that can affect the whole experience in social terms. The social aspect of a visit not only is influential for a CH experience, but social interactions also tend to facilitate the creation of long-lasting memories. The recorded data about the social context of the experience refer to: the *composition of the visit*, i.e. if the visitor comes alone or visits as part of a group; the *social environment*, i.e. are there any other people present, is it a crowded room; and the *social interaction*, i.e. do individual groups/visitors interact with other groups/visitors or museum officers and volunteers (Falk and Dierking, 1992, pp. 3, 41–54). Having stated that, it should always be remembered that a larger social and cultural environment exists. This "umbrella" defines the status of CH institutions or events and affects not only the societal aspect of the visit, but also personal motivations (e.g. social recognition) (Falk and Dierking, 2013, pp. 64–81). Nonetheless, many aspects of this umbrella can be difficult to capture.

[35] Data about the place of residence and the ethnic background of participants were only collected when approval was granted by the Tier 2 CREC of the University of Brighton. Disability data were only collected in the case study with visually impaired audiences.

The third contextual parameter is also of great importance and constitutes the focus of the research as it pertains -amongst other- to the digitally fabricated artefact. The **physical context** of the experience comprises the *physical space*, the *original CH artefact* and the *interpretative material* which supports the exhibit (fig. 17).

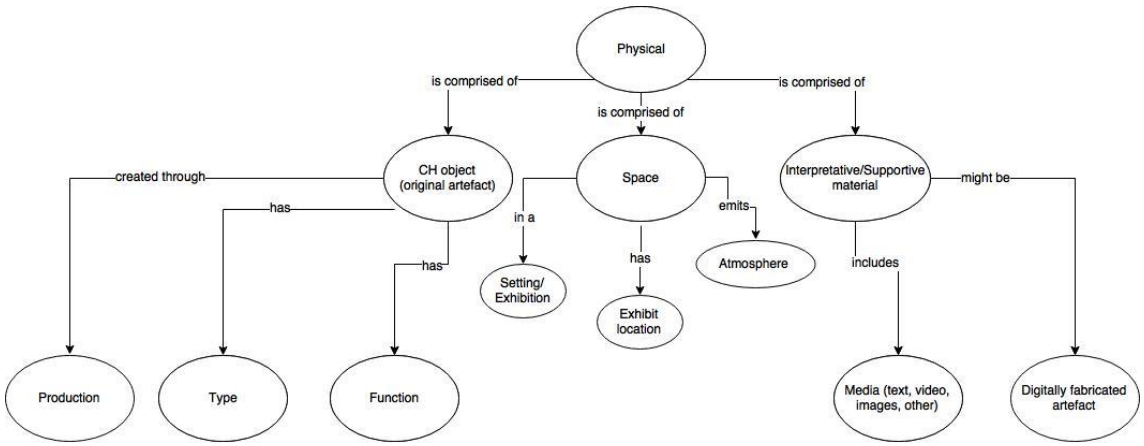


Figure 17: The physical context of the RXF.

The *original CH artefact* has a specific *type, function* (initial function and later as an exhibit) and was made through a *production* process all of which -along with other information- are documented using different models, such as the widely accepted *CIDOC conceptual reference model* (CRM) which provides a formal and extensible ontology to document CH information (Crofts et al., 2011).

Space refers to the *setting* that might be a museum or an exhibition, an institute or a public open space, a big or small building, room, hall, a novel or traditional gallery and so forth. *Exhibit location* (or arrangement) is another element of spatial information, as the exhibit might be placed near an important spatial element, on the first or second floor of a building, near or far from the entrance and it might accordingly be viewed by many or fewer visitors. *Atmosphere* describes a more abstract and vague aspect of the physical context. Thus, it can be the feeling that the exhibition emits, it can be the light in the display where the object is placed, it might be a disturbing noise in space, the carpeted or wooden floor or the overall "attracting" and "holding power" of the object (Falk and Dierking, 1992, p. 70, 2013, pp. 106, 132–133). Lastly, it should be noted that orientation information is important and -even though it does not constitute a separate element in the map- it is considered within the *exhibit location*, as it can affect the impression of the exhibit experience (e.g. a visitor might behave in different ways when seeking how to orient in a new place). Hence, it is one of the

elements CH practitioners should always pay attention to when designing an experience and exhibition (Falk and Dierking, 2013, p. 140).

There is one final "ingredient" which needs to be considered as for the physical context of the RXF. It is the *supportive interpretative material* that complements the experience and consists of analogue and digital *media* (text labels, other texts, photos, videos, audio recordings) presented in posters, banners, leaflets, interactive installations, multimedia applications and other means in the CH setting. The *supportive material* has been chosen as the most adequate frame to also place the *digitally fabricated artefact* which refers to (or uses as input) an original artefact (or the information about it) whether it is interactive or not. The reason is that it can be considered as another *manifestation* of information that complements the interpretation around a CH exhibit.

4.4 The expression of the RXF

4.4.1 Expression and perception aspects

The whole RXF is conveyed through human expression in various ways. When it comes to replicas, audience expressions can have the form of new knowledge, gained skills, emotions, behaviours, engagement, attitudes or values. It can be argued that such expressions constitute the semantic or **extrinsic** properties of a digitally fabricated artefact, i.e. the *meanings*, *values* or *opinions* that emerge when the user lives an experience with a replica within a given context (Karana, 2010). Therefore, *understanding audience's understanding* is of great importance and requires paying attention to people's impressions, accepting their perception as legitimate and deploying systematic ways to decode their opinions and behaviours. Apart from examining audience's understanding at a micro-level (with the RXF), such a task is equally significant at a macro-level, as the organisation holding an exhibition or event which deploys replicas needs to evaluate, document and maintain meaningful relationships with its audiences (and prove the effectiveness or impact of its strategies).

Before examining which are the fundamental principles that an evaluation must take into consideration, it must be clarified that the *expression - perception* aspect of the RXF goes beyond the traditional notion of school-based, marked learning. As such, expression - perception in the context of the CH experience comprises: understanding of facts and concepts, self-awareness, self-confidence, attitudes, beliefs, aesthetic appreciation, emotions, enjoyment of beauty and so forth (Falk and Dierking, 2013, pp. 218–245). Not

surprisingly, the above described wide framework to map the CH experience reflects ICOM's (2007) definition of museums which focuses on *education, study* and *enjoyment* when discussing about the communication of CH[36].

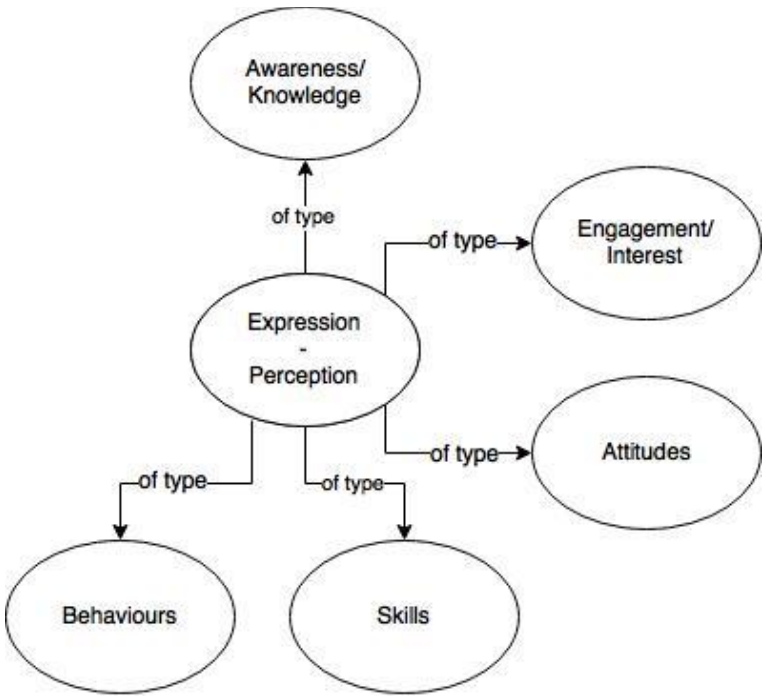


Figure 18: The expression-perception of the RXF.

To articulate the audiences' experience and thus define the "aspects" of investigation for the research (objectives 1, 4 and 5 in 1.5), the following parameters are examined:

- **Awareness or knowledge** mostly refer to cognitive aspects of the experience. Hence, they examine the acquisition of knowledge and understanding about concepts and facts.
- **Engagement or interest** belong to the emotional and affective sphere of the experience. If a visitor enjoyed an exhibit, felt inspired and is interested in becoming creative in several ways are the issues to investigate here.
- **Attitudes** bear on the effect that the experience can have on people's lives in terms of values, beliefs about phenomena and increase/decrease of self-esteem and self-confidence.

[36] A new definition for museums was proposed recently by ICOM (ICOM, 2019). The new definition did not gain the majority vote and is under consultation. Hence, the old definition of 2007 remains in force.

- **Behaviours** pertain to the behavioural changes of audiences during the visit or afterwards; and the progress they might demonstrate in various fields.
- **Skills** reflect on the thinking or practical "equipage" that people might have acquired because of the experience (e.g. how to do something, people feel that the experience benefited them in problem solving, doing research).

The above parameters (fig. 18) to measure the outcomes of a programme, exhibit or application have been influenced by the *United Way of America*'s model to perform outcome measurement for diverse organisations (Institute of Museum and Library services, 1999; United Way of America, 1996). In the UK, a similar framework was later proposed by *The Learning Impact Research Project* (Hooper-Greenhill, 2004). In 2008, in the USA, the *Division of Research on Learning in Formal and Informal Settings* of the *National Science Foundation* (Allen et al., 2008) also introduced a similar set of criteria to examine learning impact; whereas in the UK, the *Arts Council* proposed a set of *Generic Learning Outcomes* as part of the evidence to measure the impact of heritage organisations' activities. The *Generic Learning Outcomes* form part of the wider *Inspiring Learning* framework that was launched by the *Arts Council*, which has been recently refreshed under the title *Inspiring Learning for All* (Arts Council England, 2014a, 2014b). The available resources and guidance on how to deploy the *Generic Learning Outcomes* in heritage evaluation include a question bank (Arts Council England, 2014c), which has been useful for the development of the research project presented in this thesis. Similarly, Diamond at al. (2016) also present the above set of experiential aspects and propose different ways to collect and analyse evaluation data with respect to museum activities.

4.4.2 User experience and usability

At this point, it should be noted that the above described themes (awareness/knowledge, engagement/interest, attitudes, behaviours and skills) encompass the concept of user experience (UX). UX, as stressed by Preece et al. (2015, pp. 12–15), *"is about how people feel about a product and their pleasure and satisfaction when using it, looking at it, holding it, and opening or closing it. It includes their overall impression of how good it is to use, right down to the sensual effect small details have on them..."*. Hence, most of the central aspects of UX with respect to emotions, beliefs, opinions, perceptions, aesthetics, functions, values, behaviours, stimulation (International Organisation for Standardization, 2019; Preece et al.,

2015, pp. 12–15) are obviously included in the proposed map and can be "translated" into knowledge/awareness, engagement/interest, attitudes, skills and behaviours.

From the perspective of visitor and learning research, Flagg (2008) states that focus is often placed on "*what systems/programmes do for people instead of what people do with a system/programme"*, regardless of efforts to shift *"from what exhibits do to what visitors make out of exhibits"* (Miles, 1993). Responding to both faces of the same "coin" can be useful when discussing about replicas, hence this study attempts to echo both tendencies. Nonetheless, the overall approach could be perceived as of more qualitative nature as the main topic of interest is the visitor/user "living experience" of a system or product which cannot be abstracted from the context. Hence, as Adams et al. (2008) argue: *"the emphasis is not on measuring and producing numbers but instead on understanding the qualities of a particular technology and how people use it in their lives, how they think about it and how they feel about it"*. Such an understanding of the experience, apart from being more holistic (as mentioned before in section 3.4.4), it further reflects recent methodological movements which a. acknowledge that usability and user experience form an ambivalent relation (Raita and Oulasvirta, 2014) and b. suggest the evaluation of usability of ubiquitous or multi-modal systems in more "experience-driven" qualitative approaches or/and in the wild (Economou et al., 2019; Economou and Tost, 2008; Galani and Kidd, 2019; Hornecker and Nicol, 2011).

In the context of this research, usability is not ignored but rather incorporated into the "bigger picture" the RXF attempts to capture and analyse. Therefore, usability aspects are recorded mostly through observation of visitors' behaviour and user satisfaction measurement with questionnaires quantitatively, whereas qualitative analysis complements and expands findings with the outcome or perception-expression of the experience of replicas.

4.5 The properties of the digitally fabricated artefact

4.5.1 Disciplines of properties

The relationship between materials (as the *ontological* study of the matter or substance of things) and the investigation of experience (as the *epistemological* question about the way we know things) has long been discussed in philosophy. In literature, there are different approaches to the investigation and categorisation of properties of things. Researchers refer to their perception of materials in several ways, such as (Zuo et al., 2001):

- talking about the function of materials;
- discussing technical properties, manufacturing properties and sensorial properties including the knowledge and emotions that are elicited by materials.

An indication of the importance of different schemas to structure this experience and knowledge can be found in different disciplines. In *archaeological research***,** in order to explore the function of an artefact there can be: intrinsic criteria, including dimensions, density, complexity, complementarity, replication; and extrinsic criteria, including location, distribution, context (Bouissac, 2003). In *classical mechanics*, a large set of physical properties exist which includes optical, acoustical, magnetic and many other properties.

On the other hand, in the world of *aesthetical appreciation of art* there are: sensory properties (e.g. shape, texture, colour, scale), formal properties (e.g. unity, balance, movement, dominance), technical properties (appearances -i.e. colour- due to materials or techniques) and expressive properties (e.g. emotions, feelings). In *sensory physiology*, properties are distributed under the classical set of five senses and other non-traditional senses and perception mechanisms.

Lastly, in *materials' study and design* there can be sensorial and expressive meanings in materials. Sensorial properties are related to the first input that our senses receive when interacting with a material in context. The expressive properties are related to our thoughts about the materials and the attributes we assign to them after the first sensorial input (e.g. a material/object can be nostalgic, toy-like, aggressive) (Karana, 2010; Karana et al., 2009).

All these classifications provide different kinds of input and require a large number of decisions to be taken based on the questions of this research. By taking into consideration the variety of models and theoretical propositions, an operational set of properties is introduced in the following sections. This framework incorporates aspects of aesthetics, material studies and other. Nevertheless, it approaches the whole topic of properties through the lenses of *functional* properties, *sensorial* properties and *production* processes (see Appendix A for the full RXF version). At the same time, this framework accepts and recognises the importance of the contextual parameters.

4.5.2 Functional properties

The functional properties (see summary of the RXF in fig. 13) of the digitally fabricated artefacts are related to the use and function of the object within the whole experience as a means to generate other layers of information or in the sense of providing an opportunity for some kind of hands-on activity. Functional properties can be also understood in terms of tangible interaction, as the fabricated artefact apart from embodying information itself (e.g. about the visual appearance of the artefact), it can also serve as the physical embodiment of an interface. In this sense, the object becomes "smart" and can trigger some animation, audio response, projection of audio-visual content and so on. Thus, it becomes connected to the traditional interpretative media that complement the CH experience. The research and deployment of smart objects in the CH experience is considered as state-of-the-art (see MeSch, 2017), hence it has been decided to include functional properties in the concept map of the RXF.

Finally, it should always be remembered that the function of the fabricated artefact, even when used in different contexts, might refer to the function of the original artefact (e.g. use of a pottery artefact as a cooking pot -before becoming a museum exhibit- and use of its replica as a cooking pot in the educational *Stone Age* programme at the Hove museum to teach children about cooking and trading practices of the Neolithic era). Also, the sensorial information and *iconicity* (in terms of resembling the original) of the object can affect the perception of its function in its new context too (Krippendorff and Butter, 2007).

4.5.3 Sensorial properties

4.5.3.1 Stimuli, receptors and senses

Energy changes (physical and chemical) in the world are perceived through human senses, as long as *stimuli* cross the threshold of the minimum amount of energy which is needed to make them registerable by our senses. Light, for example, is a form of electromagnetic radiation energy change perceived by our vision, whereas warmth and cold are thermal energy changes registered in our thermoception sensory system. It is necessary for all these changes to be of specific intensity so that they can be detectable. This is called the *absolute threshold* and has been defined by the physicist and philosopher Gustav Theodor Fechner in his work *The Elements of Psychophysics* in 1860 (Wozniak, 1999). Fechner, based on the work of his teacher and mentor, Ernst Heinrich Weber, expanded the research on the relation between the actual

change of stimuli and the perceived change of stimuli. His output was expressed through the *Weber-Fechner law* which argues that the *Just Noticeable Difference* (JND) in a stimulus (difference threshold) is proportional to the magnitude of the standard stimulus.

Even though, the current thesis does not aim to get into detail about sensory physiology and psychophysics, as it mostly seeks to investigate people's opinions and ideas about fabricated artefacts beyond just the first sensorial input, it is useful to understand sensorial mechanisms, to better schematise the properties of replicas. Digitally fabricated artefacts, like any other object, are detected in the first instance through the human sensorial system. The responses of the sensorial system, though, can vary and will always be subjective depending on a person's will and ideas or simply on contextual parameters, affecting the ways that people experience things.

In simple words, the *sensory system* describes the part of the nervous system that receives signals both from the external environment and the inner body and processes them. Different types of stimuli are received and responded more efficiently by different kinds of receptors (i.e. nervous cells) that specialise in specific stimuli (fig. 19).

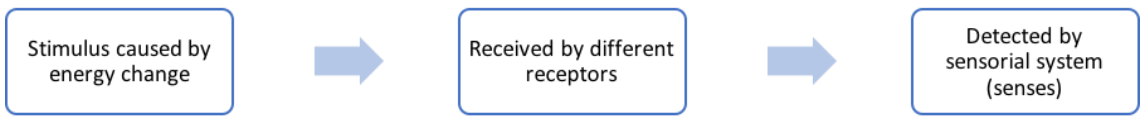


Figure 19: Detection of stimuli by receptors in sensorial system.

Sensory receptors can be classified into groups of mechanoreceptors, thermoreceptors, photoreceptors and other (Zimmermann, 1978, p. 31). Some of these receptors can be found in one organ of the human body (e.g. ear) while others are scattered widely over the body and are responsible for what is called *somatovisceral sensibility* (Schmidt, 1978a, p. 81). Here are some of the principal types of reception and their associated properties (Auffarth, 2013; Coren et al., 1999; Schmidt, 1978b):

a. *Mechanoreception* detects stimuli that are expressed through pressure, touch, vibration (acceleration) and tickle. Mechanoreception is related to touch (mechanoreception in skin) and hearing (mechanoreception in inner ear). Some of the properties which are connected to mechanoreception are *hardness* and *elasticity*.

b. *Proprioception* is the ability to be aware of the position and movement of our body. In literature, this term is sometimes interchangeable with the term kinaesthesia or kinaesthesis. The receptors of proprioception are mostly placed in joints, tendons and muscles and estimate the amount of *force* that needs to be used against a resistance (e.g. when lifting a weight).
c. *Thermoception* (or thermoreception) has the ability to receive and process warm and cold *temperature*. Thermoreceptors are placed on the human skin.
d. *Nociception* detects harmful and unpleasant situations (pain) and its receptors transmit the signal to the central nervous system. Nociception does not constitute a matter of investigation in this research.
e. *Photoreception* refers to the receptors on the retina of the eye and the ability to perceive -amongst others- *colour* and *brightness*.
f. *Chemoreception* is largely connected to taste and olfaction. Chemoreception in taste refers to the taste buds on the folds of the tongue, and their ability to detect *sweet, sour, salty* and *bitter* qualities (primary taste qualities). Chemoreception in olfaction refers to the capability of the human nose to discriminate thousands of odours. Odour perception, mechanisms and qualities are still a matter of discussion and even though there have been attempts to classify the variety of odours there is no consensus in the field.

The above classification based on the type of receptors which react to register energy changes provides a relatively systematic (still under scientific investigation) approach to connect stimuli with object properties. In order to transform these relations into a map describing the properties under a sensorial framework, the traditional set of the five senses will be adopted. This consists of *sight* or *vision*, *hearing* or *audition*, *taste* and *odour* or *olfaction*.

The importance of the role of sight, hearing and touch is obvious when studying fabricated artefacts, that people can see, touch and even tap to listen to their sound. Taste and odour should not be considered of less importance though. Smell has been recognised as one of the brain's systems which: is closer to memory retrieval; evokes emotional engagement; motivates individuals; is of fundamental importance for visually impaired and blind people; has been already deployed as a means in olfaction museum tours (Stevenson, 2014). It should also be mentioned that a fabricated artefact's odour can be noticeable (especially when

chemicals, resins and special materials such as hybrid wood are used) and museum audiences could notice that as well.

Taste should not be forgotten either as it comprises an alternative method of engagement, which can play a significant pedagogical role and inspire critical thinking in the CH experience. Taste has been recognised as a rather overlooked sense in the Western society, nonetheless it can form part of the aesthetic appreciation of an artefact (Mihalache, 2014). In accordance to these principles, museums such as the Met in New York experimented with digital fabrication and moulds to create replicas from chocolate or dough that people can taste and connect to the original artefacts in "empirical" ways (Tang and Zhao, 2015).

Finally, it is necessary to clarify that the use of the classical five-sense model does not aim to neglect the so-called non-traditional senses, such as proprioception, kinaesthesia or thermoception. Their role is accepted and taken into consideration, as described in the following paragraphs, and their properties are placed under the traditional sense that better matches their sensorial input (e.g. temperature goes under touch as it arises mostly from receptors located in the human skin).

4.5.3.2 Haptic perception, vision and perceptual constancies

Haptic perception is the term to describe the experience of the world that humans (and other organisms) have based on *cutaneous*[37] (tactile) and *proprioceptive/kinaesthetic* sensation (Giachritsis, 2008; Lederman et al., 1988). Tactile sensation refers to the sense of touch and more specifically to pressure (Paterson, 2007a); and kinaesthesia refers to the ability of humans to sense their limb and trunk position and movements. The term is often used interchangeably with proprioception. There is a debate as for whether position and movement should be considered as separate senses, stating that proprioception should be concerned with position and kinaesthesia with movement (Proske and Gandevia, 2009).

Haptic perception has long been disregarded in the Western societies where *vision* is stereotypically considered superior. Haptics have even been contempt as a lower kind of interaction with the world since ancient times. The explanation resides partly in touch's intimate/proximal nature and partly in its complexity, as it is not perceived or sensed by a

[37] Relating to the skin (hair, nails and other parts). The skin can sense pain, pressure and temperature.

single sensory organ (Paterson, 2007a, pp. 1–2). Yet, haptics are closely related to vision with respect to object recognition. Neuroimaging studies show a considerable overlap in the brain areas dealing with visual and haptic object recognition particularly for 3D shapes. In addition, it has been noted that people are able to recognise through vision something that they had previously experienced only through touch and the opposite. It is striking that -even though visual exploration dominates percept- haptic perception proves to be superior when the matter of investigation is difficult, visual information decreases and vision does not agree with touch (Coren et al., 1999, p. 239; Craddock and Lawson, 2010).

Both vision and haptic perception utilise *perceptual constancy* mechanisms (direct and indirect cues) when exploring objects. Perceptual constancy is called the perceptual systems' stability with respect to an object or the world regardless of the variety of the viewing/haptic conditions. The deployment of such a position might appear to contrast with the relativist constructive approach of the study. Nonetheless, it should be highlighted that the use of "cues" does not aim to limit the investigation to the sensorial input but rather explores ways to measure some of its aspects. Hence, this theory is mostly used to describe and position the sensorial properties of the fabricated artefacts, as they are closely connected to the features that can be manipulated through digital fabrication as well. Other aspects of the constancies deriving from the knowledge, motivation and expectation frame (i.e. the creation of hypotheses about an object's shape, size or other property) (Coren et al., 1999, pp. 324, 330–331; Klatzky and Lederman, 1995): contribute to the overall explanation of constancies; provide a multi-layered analysis of the processes which is close to computational theories; are represented in the RXF concept map.

The first perceptual constancy to examine is *size* constancy. This mechanism helps us to assign a size to an object in consciousness regardless of its distance by using cues about the object's perceptual size (direct input) and its surroundings (indirect input). Visual cues about an object's size can be both direct and indirect. Haptic exploration is limited to fewer only direct cues, such as the spread of the fingers in the initial contact and the sequence of contacts, but relatively more reliable for exploration (Berryman et al., 2006; Lederman et al., 1988).

The second constancy is *shape*. Shape constancy refers to the recognition of an object's shape regardless of its orientation (i.e. distance from different parts of the object). The mechanisms here are similar to the ones used in size. Both an object's size and shape suggest how it should

be grasped, thus as Craddock and Lawson (2010) suggest *"an accurate representation of size is important for object manipulation"*.

Brightness (or lightness or whiteness) is the constancy which depends on two factors: the amount of external light falling on an object and the proportion of the light which is reflected to the eye of a person. The characteristic example of the white sheet of paper, that we view in bright sunlight and in a dimly lighted room yet perceiving the paper as being white, is indicative of the brightness constancy.

Colour (or hue) constancy is the capability to abstract information about the colour of an object even though the spectral composition of the light which falls on it might be different. Hence, an object with a certain colour will still appear as being of this certain colour under fluorescent, white of incandescent light (with limitations though).

Finally, *texture* constitutes a separate property that humans detect through haptic information (touch and kinaesthesia). Nonetheless, texture is often incorporated into the perception of hardness (Coren et al., 1999, p. 239).

Taking into consideration the above set of constancies, one could wonder whether these can be associated to a specific sense. This task might be easier for the constancies of colour and brightness where vision dominates. Texture, as already described, can be placed under touch and examined through hardness. Nonetheless, size and shape present extra difficulties as both vision and haptic perception are deployed in their recognition. For this reason, size and shape constancies are placed under both senses as this choice seems the most appropriate. Furthermore, this classification respects all participants of the research including visually impaired audiences, who can only experience a replica's shape and size through haptics, and sighted audiences, who can also deploy vision and haptics to interact with an object.

4.5.3.3 Distribution, dimensions and measurement of sensorial properties

A large set of properties regarding digitally fabricated artefacts has already been identified under the sensorial reception mechanisms and the perceptual constancy phenomena. At this stage, it is important to move a step further and create a comprehensive map to distribute the properties of fabricated artefacts under the traditional five-sense classification by examining which sense better matches the type of the sensorial input (fig. 20). Such an undertaking should be perceived, though, as an effort to move towards a procedural framework for properties. For example, in some cases a sense will be prioritised even though

another sense might play a significant role in the sensorial process at the same time (e.g. temperature placed under touch).

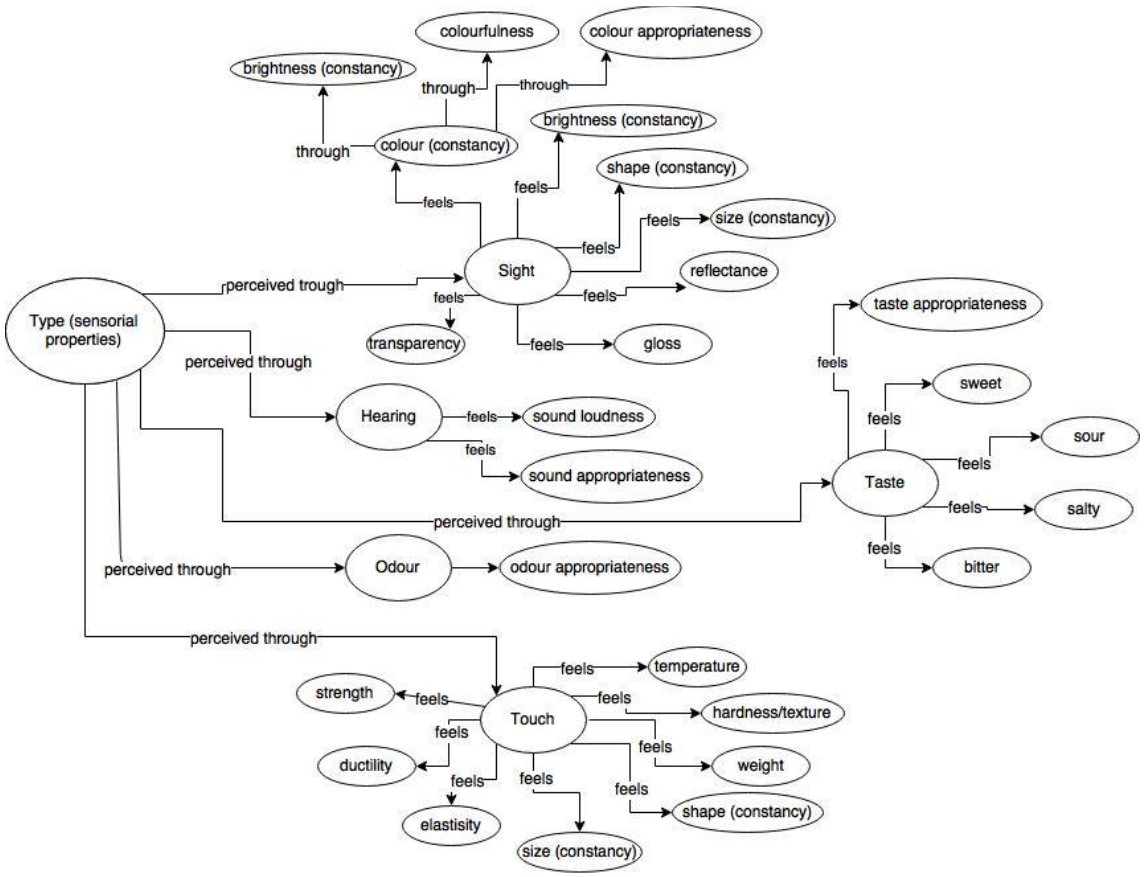


Figure 20: The sensorial properties of the digitally fabricated artefacts. This part of the concept map describes the type of the fabricated artefact which is "captured" in the first instance by our senses.

The explanatory lists and tables (tables 6-10) in the following five subsections provide a set of elements that characterise and document the CH replicas themselves. Moreover, the lists can constitute along with the production processes a theoretical and practical framework to guide stakeholders, whenever an artefact is to be digitised to be used as supportive interpretative material in the CH experience. Of course, this information does not aim to dictate choices or provide definite solutions and it should be perceived as a rather comprehensive and valuable map depicting all the factors that will influence professionals' decisions and audience's impressions accordingly (see 8.4.2.1 for further guidance on how to deploy the RXF).

The lists also include information about the dimensions of the subjective sensorial properties. Subjective properties are closely related to measuring the "affordances" of the physicality of objects based on what people can do with them or what they think about them. Therefore,

weight's subjective property is not perceived in terms of pounds or kilos (i.e. no tool or apparatus is needed). Subjective sensorial properties can be measured in terms of subjective impressions and opinions. For instance, measuring the sensorial intensity (*magnitude estimation*) can be recorded when asking how cold/warm something feels (Cunningham and Wallraven, 2012). A relative type of measurement, used in this research, is on a hedonic/satisfaction measurement that can record audiences' opinions about a given property by evaluating the likeliness/appropriateness (or not) of the feeling of it (Lim, 2011; Lim et al., 2009; Pimentel et al., 2016). The purpose is to clarify both the "things that are measured" to respond to the questions of this research (see RQ2) and the "things to be taken into account" by the CH professional, education officer or whoever is interested in designing and delivering for an experience with the use of a digitally fabricated artefact.

4.5.3.3.1 Vision or sight

Sense of vision or sight			
Property	**Sub-property**	**Dimensions**	**Measurement**
Transparency		Transparent - opaque	Subjective visitor satisfaction (on a rating scale)
Gloss		Glossy - matte	
Reflectance		Reflective - non-reflective	
Size (constancy)		Very appropriate - not appropriate	
Shape (constancy)		Very appropriate - not appropriate	
Brightness (constancy)		Bright - dark	
Colour (constancy)	Colourfulness	Colourful - colourless	
	Brightness (constancy)	Bright - dark	
	Colour appropriateness (quality)	Very appropriate - not appropriate	

Table 6: Properties, sub-properties, dimensions and measurements of sight. Colour appropriateness is rather a quality but is added in the properties of the proposed concept map to serve the research questions.

The properties examined in this research under **vision or sight** are (Coren et al., 1999, pp. 87–88, 148, 324–346; Klatzky and Lederman, 1995; Nefs, 2007) (see table 6):

- **Colour** refers to the constancy of colour and is also related to brightness as colour appearance can be described by the *colour appearance parameters* of

hue, *saturation* and *brightness* (*Munsell colour system*). Saturation on the other hand is connected to *colourfulness* and can be described in terms of something being *colourful* or *colourless*. Hue's dimension in this research is not examined as for the degree to which a fabricated object can be described as similar to or different from an original object that is red, green, blue, and yellow. Instead, it concentrates on *colour appropriateness* and measured, as the rest of the properties, on a satisfaction rating scale evaluation.

- **Brightness** refers to the constancy of brightness and is related to the physical measures of *illuminance* and *luminance*. In terms of people's perceptual impressions about light intensity (subjective brightness), it is associated with the amount of light which is emitted from a source or reflected from a surface. Brightness' dimensions refer to something being *dark* or *bright*. Brightness is measured on a satisfaction rating scale.
- **Lightness (reflectance)** refers to the constancy of brightness and describes the impression of the percentage of the light which is reflected on a surface relative to the total light falling on the surface. Lightness is associated to the physiological measure of *reflectance*. Reflectance is often a more comprehensive term (even though lightness constitutes the right term) thus it is favoured in the concept map. Reflectance's dimensions concern the *reflectiveness* or *non-reflectiveness* of an object. Reflectance is measured on satisfaction rating scale.
- **Transparency** is associated to the ability of light to pass through an object without getting scattered. Transparency constitutes a modality to which people refer often when interacting with a fabricated artefact. The dimensions of transparency indicate if something is *transparent* or *opaque.* Transparency is measured on a satisfaction rating scale.
- **Gloss** indicates how well a surface reflects light in a specular direction. Gloss is placed under sight as one of the parameters of the visual appearance of an object and a modality to which people refer to often (especially for 3D printed artefacts in PLA and ABS). Glossiness refers to whether an object is *glossy* or *matte*. This property is measured in terms of satisfaction too.

- **Shape** (constancy) constancy has been explained in the previous sections. Shape in terms of haptics is associated with a *contour following movement/glance* and an *enclosure movement/glance* towards the object. For the purposes of this research, shape is measured in terms of satisfaction in order to reflect the *appropriateness* of a fabricated object.
- **Size** (constancy) has also been explained in the constancies section. Size in terms of haptics is also associated with an *enclosure movement/glance* towards the object. Size can be measured with respect to its ratio to the original object when measuring the objective properties of an object. When measuring its subjective properties, size is measured in terms of satisfaction in order to reflect the *appropriateness* of a fabricated object.

4.5.3.3.2 Touch

Sense of touch		
Property	**Dimensions**	**Measurement**
Temperature	Warm - cold	Subjective visitor satisfaction (on a rating scale)
Hardness/texture	Smooth - rough	
Weight	Light - heavy	
Size (constancy)	Very appropriate - not appropriate	
Shape (constancy)	Very appropriate - not appropriate	
Elasticity	High - low	
Ductility	Ductile - tough	
Strength	High - low	

Table 7: Properties, dimensions and measurements of touch.

The properties examined with respect to **touch** are (Coren et al., 1999, pp. 324–339; Karana et al., 2009; Klatzky and Lederman, 1995) (see table 7):

- **Temperature** (thermoception or thermoreception) is the sense that an organism uses to perceive heat and cold. The details of how thermoception works are still being investigated. Temperature is placed under the sense of touch as it arises mostly from *static contact* with the object and receptors located in the human skin. The dimensions of temperature are perceived in

terms of feeling an object as being *warm* or *cold*. Temperature is measured on a satisfaction rating scale.

- **Hardness/texture** is associated with a movement tangential to an object's surface (*lateral motion, friction*). Hardness and texture, in terms of dimensions, can characterise something as being *rough* or *smooth*. Texture here is measured on a satisfaction rating scale.
- **Weight** belongs again to the sphere of visual-haptic perception, as it includes: the calculation of the amount of force to put into weight lifting through proprioception and kinaesthesia, past knowledge/information (familiar weight), visual direct and contextual cues (e.g. is the object dense or does it float?) and touch. Weight is associated with *unsupported holding* of the object. The dimensions of weight refer to an object that can feel *heavy* or *light.* Weight is measured with respect to the original artefact and visitor's feedback will be used to identify whether the object has a satisfactory weight.
- **Shape** (constancy) has been analysed under the vision/sight sense.
- **Size** (constancy) has been analysed under the vision/sight sense.
- **Elasticity** refers to the ability of the object to return to its previous state when *pressure* is applied to its surface. Elasticity's dimension ranges from *low* to *high* elasticity. Elasticity is measured on a satisfaction rating scale.
- **Ductility** is also connected to *pressure* and is related to the object's ability to deform when pressure is applied to it. Hence, its dimensions refer to an object as being *ductile* or *tough*. Ductility is also measured on a satisfaction rating scale.
- **Strength** is related to the amount of force that an object can handle before breaking. Strength can be measured on a satisfaction rating scale and an object can be designed to have *low* to *high* strength.

4.5.3.3.3 Hearing

Sense of hearing		
Property	**Dimensions**	**Measurement**
Sound loudness	Very loud - not loud	Subjective visitor satisfaction (on a rating scale)
Sound appropriateness (quality)	Very appropriate - not appropriate	

Table 8: Properties, dimensions and measurements of hearing. Sound appropriateness is rather a quality but is added in the properties of the proposed concept map to serve the research questions.

Hearing depends on the presence of sound waves which are actually pressure changes generated by vibrating molecules. Apart from the classical properties of sound, i.e. *loudness* and *pitch*[38], more properties have been proposed, such as *perceived location* and *duration of sound, timbre, volume, density, consonance or dissonance* (Coren et al., 1999, pp. 194–206). As this set of properties is not only difficult to perceive but also to measure, for the purposes of qualitative research -when the sound produced by a fabricated artefact is to be examined- **sound loudness** and **appropriateness** can be measured on a satisfaction rating scale (see table 8).

4.5.3.3.4 Taste

Sense of taste		
Property	**Dimensions**	**Measurement**
Sweet	Very sweet - not sweet	Subjective visitor satisfaction (on a rating scale)
Sour	Very sour - not sour	
Salty	Very salty - not salty	
Bitter	Very bitter - not bitter	
Taste appropriateness (quality)	Very appropriate - not appropriate	

Table 9: Properties, dimensions and measurements of taste. Taste appropriateness is rather a quality but is added in the properties of the proposed concept map to serve the research questions.

The properties of **taste** are (Altner, 1978, pp. 221–222): **Sweet, Sour, Salty** and **Bitter**. Taste should be included in measurements whenever an edible artefact is created, usually by pouring/putting some edible substance in a mould which is produced through digital

[38] Pitch refers to subjectively positioning a musical tone on a musical scale at a higher or lower level. Pitch is related to the frequency of the vibration of a sound.

fabrication (3D printers directly printing with edible materials also exist). Estimating *taste intensity*, though, might be problematic due to the large number of factors that affect it (stimulus concentration, application of stimulus in different parts of the tongue, mixtures of stimuli, age of participant and other) (Coren et al., 1999, pp. 217–218). Thus, it can be suggested that in a study involving edible replicas, researchers could measure what people think about the *taste* of the object. They can also examine **taste appropriateness** (i.e. on a satisfaction rating scale) (see table 9).

4.5.3.3.5 Smell

Sense of smell		
Quality	**Dimensions**	**Measurement**
Smell appropriateness (quality)	Very appropriate - not appropriate	Subjective visitor satisfaction (on a rating scale)

Table 10: Qualities, dimensions and measurements of smell. Smell appropriateness is rather a quality but is added in the properties of the proposed concept map to serve the research questions.

The properties of **smell** and odour perception mechanisms are still a matter of scientific discussion and in many cases "suffer" from the same factors affecting taste. Even though there have been attempts to classify the variety of odours and different methods to measure them have been proposed, there is no consensus in the field. The difficulty to define linguistically the terms to describe odour make the situation even more difficult and refer to the "tip-of-the-nose" phenomenon, where people cannot find the words to describe odour. Nonetheless, one of the most salient dimensions in odour measurement is *pleasantness* (Auffarth, 2013). Pleasantness, though, does not always agree with appropriateness in terms of something smelling nice but not appropriately with respect to the replica of the object that it represents. For this reason, comments about smell from the participants can be recorded and **appropriateness** can be rather measured on a satisfaction rating scale (see table 10).

4.5.4 Production processes

4.5.4.1 Material selection and processes

After analysing the sensorial properties that describe the fabricated artefacts another key concept needs to be added in the concept map. This is the *process* that allows the **production** of the fabricated artefact itself. The process is equally important to the selection of the appropriate material to fabricate an artefact. The material and its *affordances* will sometimes: support the choice of a specific process; dictate mechanisms for manufacturing needs (e.g.

joining); and drive technological developments in the field of digital fabrication. However, the process can indicate the right material to use too when creating an object. Respectively, both of them can largely influence how audiences experience an object and attribute several meanings or values to it (Ashby et al., 2010, p. 2; Karana, 2010; Karana et al., 2009).

A characteristic example demonstrating the power of the interaction between process and material is the comment of many archaeologists and CH professionals who -when asked by the researcher to express their opinion about 3D printed replicas of ancient ceramic pots in glossy ABS- commented on their toy-like appearance and function. One logical explanation here is that the choice of a relatively cheap material that resulted in light, glossy replicas affected the meanings that CH professionals attached to them based on the sensorial input.

It can be, thus, understood that material selection is a parallel action of great importance in the production of the digitally fabricated artefact. Nonetheless, material selection refers to: a. fast developing material sciences that include their separate processes and b. a choice that happens and can change in various stages of the production workflow. For this reason, material selection is not included in the concept map, yet it should be considered as a permanent action throughout production.

4.5.4.2 Production and theoretical background

Analysing production processes and selecting between hundreds or thousands of options is a large field of study and training for engineers and product designers. It is practically impossible to include all this fast-evolving information into a concept map describing the production of CH digitally fabricated artefacts. Therefore, the concepts described in the map take into consideration the current status in the domain of digital fabrication and the ways that this technology is mostly deployed to serve the communication of CH information. To this purpose, the proposed concept map draws on: Ashby et al. (2010, pp. 17–20) families and classes of manufacturing processes; its deployment by Karana et al. (2009) who managed to reduce the extensive list of methods (and properties) described in the *Cambridge Engineering Selector* (created by Ashby and his colleagues) after examining their list with industrial design engineers and professional engineers; the analysis and categorisation survey of Scopigno et al. (2015) about digital fabrication technologies for cultural heritage.

At this point and before proceeding with the different kinds of processes and sub-processes in the concept map, the choice of the term *production* needs to be justified. *Production* has

been selected as this word encompasses all processes that are needed to get from the original design (or 3D model in our case) to manufacturing, resulting in the fabricated artefact that is used to engage CH audiences. *Manufacturing* now should be understood as the process by which raw materials are converted into finished products and has a more technical aspect.

4.5.4.3 Production processes and techniques

The production processes of the digitally fabricated artefacts describe the variety and often the sequence of processes that begin with the acquisition of the geometrical information and appearance of the artefact and end with the finished product which is used in the CH experience (fig. 21).

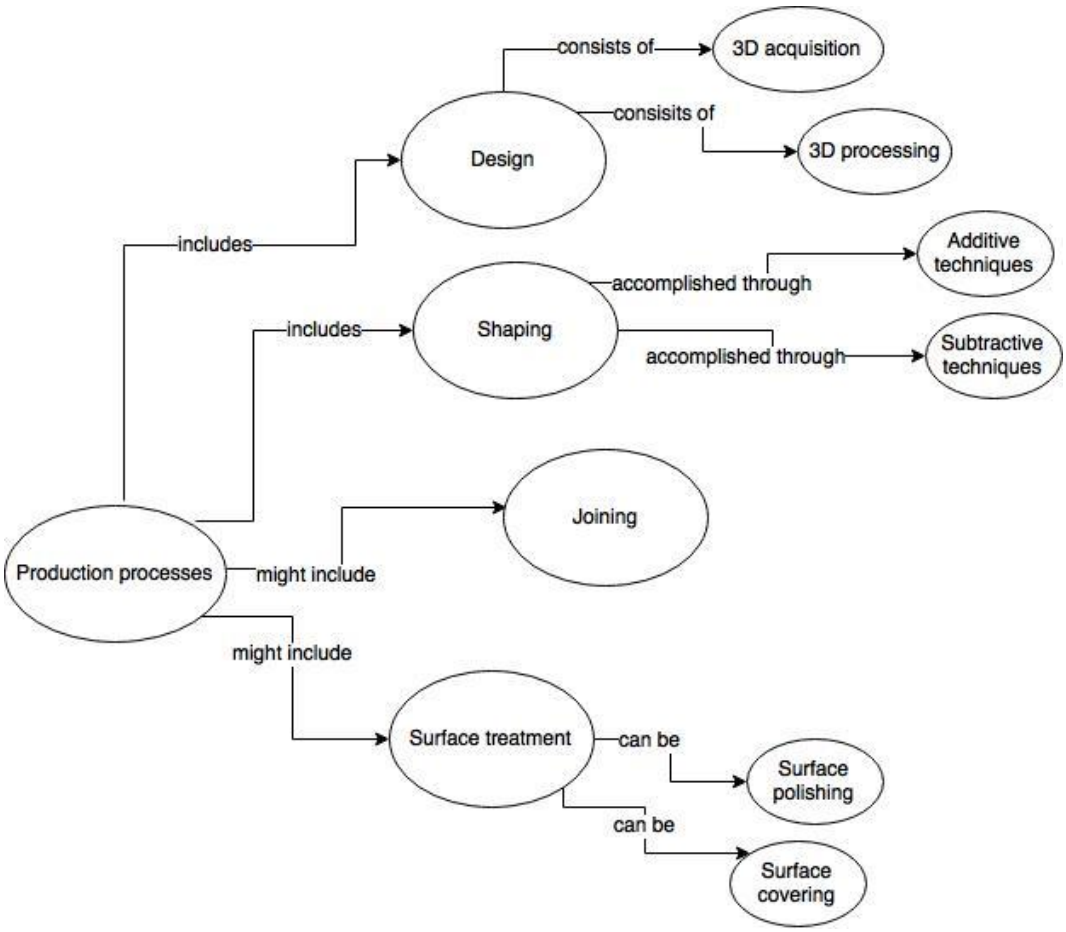


Figure 21: The production processes of the digitally fabricated artefacts.

The production of the fabricated artefact starts with the **design** phase which refers to the *acquisition* of the shape (and in some cases the colour as well) information of the original object and its *processing*/*editing* for fabrication. The acquisition can be the result of 3D scanning, photogrammetry, CT scanning or other technology. Nonetheless, the 3D mesh of an artefact can also be manually modelled, downloaded through free libraries (e.g.

Thingiverse, SketchFab) or even bought online. Processing can be related to a variety of editing actions that will result in the high-quality 3D model which is ready for fabrication. Processing can finish with the creation of a ready-to-fabricate 3D model in 3D software (editing design) or it might deploy further actions, such as simplifying a model or digitally fragmenting the model and creating joints, to end up with the ready-to-fabricate 3D model/s (design for manufacturing).

Shaping is the next process which includes taking a 3D model and producing code for a machine to physically fabricate it. Shaping can be accomplished with the use of *additive* or *subtractive techniques* (see section 2.2.3). The successive use of both techniques cannot be excluded either as often the shape of an artefact will be used to create a "negative" shape which then will be used as a *mould* to create the "positive" shape or replica of the original object. Hence, moulding should be considered as an important technique which can belong to both parent techniques. Often the selection of the appropriate technique is a matter of choice based on a set of criteria including: cost of the technology, ease of use, geometric freedom, material adequacy to CH, precision and working size (Scopigno et al., 2015).

Production processes		
Process	**Sub-process**	**Examples of techniques and tools**
Design	Acquisition	3D scanning
		Photogrammetry
		CT scanning
		3D modelling (manual modelling in 3D software)
		Downloaded/bought 3D model
	Processing	Editing design
		Design for manufacturing (simplifying, fragmenting, joints' creation and other)
Shaping	Additive techniques	Powder methods and special methods (fused deposition modelling, laminated object manufacturing, gypsum binding, metal sintering, plastic sintering, photopolymerisation and other)
		Moulding (e.g. sand casting, silicone moulding)
	Subtractive techniques	CNC machining (2.5D CNC Carving, 6-Axis CNC Carving and other)
		Moulding (e.g. sand casting, silicone moulding)

Production processes		
Process	**Sub-process**	**Examples of techniques and tools**
Joining		Functional/decorative fastening (bolts, screws, fasteners, rivets, snap fits and other) and/or undetectable joining adhesives and welding (glues, cement, adhesives, heat bonding and other)
Surface treatment	Surface polishing	Polishing, sanding/texturing
	Surface covering	Painting, coating, plating, metallising, chromising and other

Table 11: Production processes, sub-processes and examples.

The next phase is **joining** which does not constitute an obligatory step in the production of a digitally fabricated artefact (see table 11). Joining will mostly become necessary when the fabricated object is in pieces and needs assembly, so screws, bolts and other means can be used to synthesise it. Functional/decorative fastening refers to detectable joints such as screws, bolts, snap fits and other and/or undetectable joining methods which deploy glues, heat bonding and other kinds of adhesives.

Lastly, there is the phase of the **surface treatment** (see table 11) which includes all the actions that one would undertake to *polish* the surface of the fabricated artefact by applying chemicals (e.g. acetone on ABS) or by sanding/texturing the object. It also includes the surface *covering* actions by painting, plating or metallising the artefact. Surface treatment is not obligatory either as the object might not need this kind of post-process when produced.

4.6 Intrinsic and extrinsic properties

Based on the theoretical proposition that has been presented in this chapter it is possible to conclude by presenting the set of properties which belong to the intrinsic and extrinsic aspect of the digitally fabricated artefacts. These are:

a. The **intrinsic properties** are the *internal properties* of the fabricated artefacts. They mostly consist of *physical properties* which are translated into *subjective properties* that can be measured based on people's rating and feedback (no device/tool measurement is needed). Therefore, the intrinsic properties are initially "captured" through our senses and can be found in the **sensorial properties**' section of the proposed map.

b. The **extrinsic properties** are the *relational, semantic or expressive* properties of the fabricated artefacts. These reflect the skills, knowledge, attitudes, values, behaviours

and emotions that the audiences experience, live and express with respect to a replica within a given context. These expressions could be described as a constant dialogue between the sensorial properties, the function and production of the replica within the personal/physical/social context in which the object is experienced by the CH visitor. Of course, extrinsic properties can change over time and are always interconnected to the above parameters. The way to decode the extrinsic properties of replicas is to look at the **perception and expression** of the CH experience as lived by CH audiences and presented in the RXF.

4.7 Summary

The RXF concept map has been presented in this chapter. The proposed map constitutes the framework based on which an experience with the use of a replica could be designed, produced, realised and evaluated. Such a framework incorporates the contextual and expressive parameters that define a CH experience:

- The personal context which comprises information about visitor demographics and background;
- The social context of the visit which refers to situational aspects such as the composition of the visit, the environment of the visit and the interactions that take place between visitors and groups;
- The physical context which, apart from the exhibition space and the original exhibit, includes the interpretative, supportive material. This is where the digitally fabricated object is placed as a means to convey, through its properties, the sensorial input that will be further elaborated and result in expressive meanings;
- The expression/perception of the experience where a digitally fabricated object has been deployed and the "outcome" of such an experience in a broad definition of appreciation and learning. Here the effects of the experience are evaluated in terms of knowledge/awareness, engagement/interest, attitudes, skills and behaviours.

The theoretical analysis of each one of the above parameters largely drew upon research in the fields of psychophysics, cognitive psychology, perception theory, visitor and museum evaluation research, aesthetics, media and product design studies.

The chapter also presented information on the function of replicas, the production processes which lead to their creation and their sensorial properties. The sensorial properties were analysed based on the traditional five-senses classification and ways to evaluate them have been introduced. Finally, the intrinsic properties of the digitally fabricated artefacts have been recognised as those pertaining to the sensorial spectrum of the experience, whereas the extrinsic consist of the meanings, values, attitudes, interest and other aspects of the experience that people associate with them.

The chapter that follows is dedicated to the development of first case study of this research and the analysis of its findings.

5 Chapter 5: Case study 1 – Kittiwake relief

5.1 Introduction

This chapter is dedicated to the first case study of the research, which involves the exploration of a 3D printed relief representing an environmental display from the Booth Museum by visually impaired audiences. The chapter (as well as all case studies' chapters) is structured along the lines of exhibition development: *planning*, which discusses the inspiration, ideation and concept of the case study; *development/design* phase, which describes the main "ingredients" of the study as well as the development and production of assets and available resources; and then setting up the exhibit and *evaluating* with audiences; in order to present the *findings* of the case study (Dean, 1996, pp. 8–18; Locker, 2011, p. 36). Similar to exhibition design, case studies' literature adopts a similar sequence of processes (Yin, 2009).

The findings of the case study are structured in accordance with the RXF, as described in Chapter 4. Thus, results are analysed within the personal, social and physical context in order to illuminate the variety of parameters defining the CH experience. Data of quantitative nature about the properties of the relief are included in the physical context (replicas are part of the interpretative/supportive material in the RXF, see section 4.3). Lastly, all the results about the expression and perception of the experience refer to the five key themes of: awareness/knowledge, engagement/interest, attitudes, skills and behaviours (section 4.4), while other themes that have emerged inductively and/or deserve special attention are also mentioned separately.

5.2 Planning the study

The case study investigates how a specific target audience responds to the presence of a digitally fabricated artefact within a context-dependent CH experience. The first step was to start thinking about the experiential framework based on the RXF, hence the contextual parameters or "ingredients" of the case study, i.e. the target audience, the object to replicate and the collection/gallery it belongs to, complementing media and the overall purpose of the replica and resources in order to be able to proceed with the realisation of the case study (see 8.4.2.1 for further guidance on how to start thinking about the contextual parameters of a replica experiential framework based on the RXF). A variety of resources provided valuable input at this stage too, such as: extensive document review; participation in CH events where

replicas were presented to audiences; discussions with heritage professionals and researchers working in the field of 3D imaging and digital fabrication. Some initial ideas were generated based on this input, focusing on providing a replica to visually impaired audiences within an interpretative framework and record people's opinions about the replica's properties and its overall contribution to the experience. The Booth Natural History Museum was selected for the case study, as it constitutes one of the least accessible museums of the RPM for visually impaired people. All recent *Audience Development Plans* (2016a, 2018) for the Booth Museum explicitly mention the need to facilitate access to the museum's resources for disabled audiences (both in terms of infrastructure and interpretation). At the time of discussions about the case study, the museum was part of the *Sensing Culture* project (Van Hesteren, 2016), investigating ways to make the collections of the Booth more accessible for blind and partially sighted people.

Several visits to the Booth museum and meetings with RPM's outreach officers followed. During a *museum walk*[39] it was suggested that -even though 3D imaging and printing could be more easily employed for the fossil and bone collections of the museum (because of the type of materials and full access for digitisation purposes)- it would be interesting to investigate how the *environmental displays* or *dioramas* of the museum could be made accessible to the visually impaired. The challenge with the dioramas, which constitute the main exhibits of the museum, is that the contents of the displays (i.e. birds and animals in scenes representing their natural habitat) are placed behind glass in badly lit environments and are stacked along the walls of the museum (fig. 22), making them extremely inaccessible for people with sight difficulties.

[39] Museum walks or field walks can be methodological tools to inspire the design of an exhibit or application. While moving, creative ideas are discussed and opinions are shared about the design concepts and requirements of visitors (Avram and Maye, 2016).

Figure 22: The dioramas stacked along the walls of the Booth Museum.

Based on these discussions and further meetings to investigate requirements with the project's (*Sensing Culture*) disability advisor, it was decided to develop a solution for a tactile experience with the use of digital fabrication. The objective would be to support visually impaired audiences to access the otherwise non-accessible displays of the Booth Museum with an -as much as possible- multisensorial experience by delivering tactile and auditive information. Then, the benefit of the experience would be investigated not only in terms of knowledge, but also at an engagement, attitudinal, emotional and behavioural level (Diamond et al., 2016, pp. 15–16).

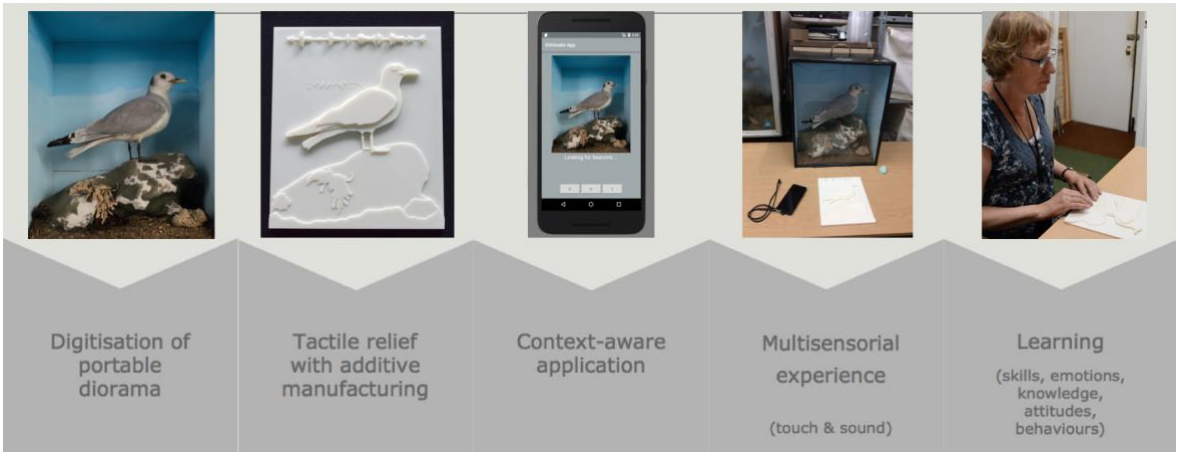


Figure 23: The proposed solution for the Booth Museum case study.

The proposed solution involved the digitisation of a diorama from the museum, the production of a 3D relief and the development of a context-aware mobile application to support visitors with auditive information when exploring the relief (fig. 23).

5.3 The development and design of the study

This section describes the next phase in the realisation of the case study, providing precise details about the contextual parameters or main "ingredients" of the experience. It includes information about the CH organisation and exhibition/collection, the target audience and the design and development of the relief and application for the case study, as well as information on the technology and available resources (see 8.4.2.1 for further guidance on how to deploy the RXF for the design of a replica experiential framework).

5.3.1 The Booth Museum

The Booth Museum was founded in 1874 by Edward Thomas Booth (1840-1890), a wealthy man who developed a passion for wildlife and hunting from a young age (fig. 24). Booth's museum was not initially open to the public and it was a private space to create, study and preserve his collection of *environmental displays* or *dioramas*. In an effort to exhibit an example of every single living species of British bird, Booth started expanding his collection which by the end of his life consisted of 300 cases. The museum came to Brighton civic ownership in 1891. In the 1970s its exhibits were enriched with fossils, bones, insects, minerals and rocks coming from other local collections. In 1998, the Booth collections have been designated as being of national importance (Royal Pavilion & Museums, 2012).

Figure 24: The Booth Museum in Brighton (left) and Mr Edward Thomas Booth (right) (Wikimedia under Creative Commons and Royal Pavilion & Museums, 2012)

The largest part of the exhibition at the Booth Museum consists of its founder's dioramas. These dioramas, which became very popular in the late 19th century, usually present taxidermic specimens (mostly stuffed birds) in a scene replicating their natural habitat. The scene is usually encased in a glass display with painted side and back walls. Environmental displays constituted a powerful medium to communicate and influence ideas about the environmental perception, following changes that had already occurred in the interpretation of nature in the 19th century. Hence, the main purpose of these displays in the Victorian era was to associate species to their natural surroundings and provide an "ecological" view of the natural ecosystems. Nature was not "isolated" anymore, but rather perceived in connection with a broad biological reality, landscapes, geographical distribution, origin of species and animal behaviour (Wonders, 1993).

Nowadays, standards and perceptions around nature preservation have changed. Killing an animal to showcase it for exhibition purposes might not be considered as moral. Nonetheless, it is important to protect, preserve and communicate the ideas behind exhibits, such as Booth's dioramas, in order to record and understand past scientific practices and museological approaches, which undeniably form part of our ever-evolving heritage.

5.3.2 Target audience

Visually impaired participants with total blindness or partial sight were chosen as the target audience for this study. All participants were adults having acquired visual disability at birth (congenitally) or at later stages of their lives due to trauma, declining vision or other reasons (see 3.4.9).

As stated before, this particular group seems to be amongst the people who can benefit the most from tactile experiences with the involvement of digitally fabricated replicas (see section 2.5). Furthermore, RPM's management was interested in providing better services to disabled audiences by improving Booth's premises (ramps, guidance in corridors, front desk support and other) as well as enriching exhibitions with accessible interpretative material.

5.3.3 Development of 3D relief and context-aware application

5.3.3.1 Design and production of 3D relief

When exploring the solutions that would allow to create a replica representing the contents of the selected diorama, all possible digitisation techniques were considered. Methods that are typically used to acquire the shape of a heritage artefact are photogrammetric processes, industrial scanners and depth-sensing devices like Kinect. In literature, there were no examples of environmental displays that had been digitised in 3D and reproduced with the use of digital fabrication, which could be examined or used as examples. Moreover, several difficulties had to be addressed by overcoming obstacles with respect to imaging and fabrication. Firstly, dioramas present reflections on the glass of the display making acquisition extremely difficult. Another difficulty is the encased nature of the exhibit which eliminates the possibility for a 360 or even a 180-degree acquisition. Lastly, even if the scene of the diorama was not encased in glass, the digitisation and mainly the fabrication of birds, plants and other natural species is an issue that has not been solved yet (lack of realistic representations, materials and colours for digital fabrication).

Given such challenges, it was not possible to use 3D sensing methods. Instead, it was deemed necessary to digitise in 2D and work with a 2D image in order to extract information about the shapes of the contents of the display. Hence, the scene was presented in the form of a relief similar to other tactile material -coming mostly from the field of visual arts, such as photography and paintings- for visually impaired audiences.

The chosen diorama presents a kittiwake standing on a rock and gazing across the horizon and is a late acquisition of the museum (fig. 25). The main criterion for its selection was that it is portable. This allowed experimenting with the photographic acquisition and facilitated easy transfer for testing and evaluation.

Figure 25: The portable diorama from the Booth Museum showcasing a kittiwake.

In literature, different workflows have been proposed for the creation of reliefs from 2D images. They mostly use various methods to extract contours, to segment parts of a picture, to control volume information and to simplify the image (Carfagni et al., 2012; Ferro and Pawluk, 2013; Furferi et al., 2014; Lorenzini et al., 2013; Reichinger et al., 2011). Nevertheless, all these methods generate too much information and create cluttered representations which might confuse a visually impaired user. Therefore, additional manual work or "interpretation" is required to convey the important elements of a scene.

For this case study, the deployed workflow used a high-quality image of the environmental display. This was acquired with a DSLR camera by using a polarising filter and tilting the camera upward at an angle to the object. Also, a piece of thick black fabric with an opening for the camera lens was used to eliminate reflections on the glass of the display (fig. 26).

Figure 26: The setup for the acquisition of the diorama.

Then, the raster image file was imported into a vector graphics software in order to trace the most important elements of the scene (fig. 27). Some of the decisions that were made at this stage with respect to simplification were to present the kittiwake in a fully profile view (which is more easily understood by blind people) and avoid overlaps by omitting objects of the scene (Braille Authority of North America and Canadian Braille Authority, 2011; Perkins School for the Blind, n.d.; Reichinger et al., 2011). The *Decision Tree* for the creation of tactile graphics was particularly useful during these processes (Hasty and Seki, 2004).

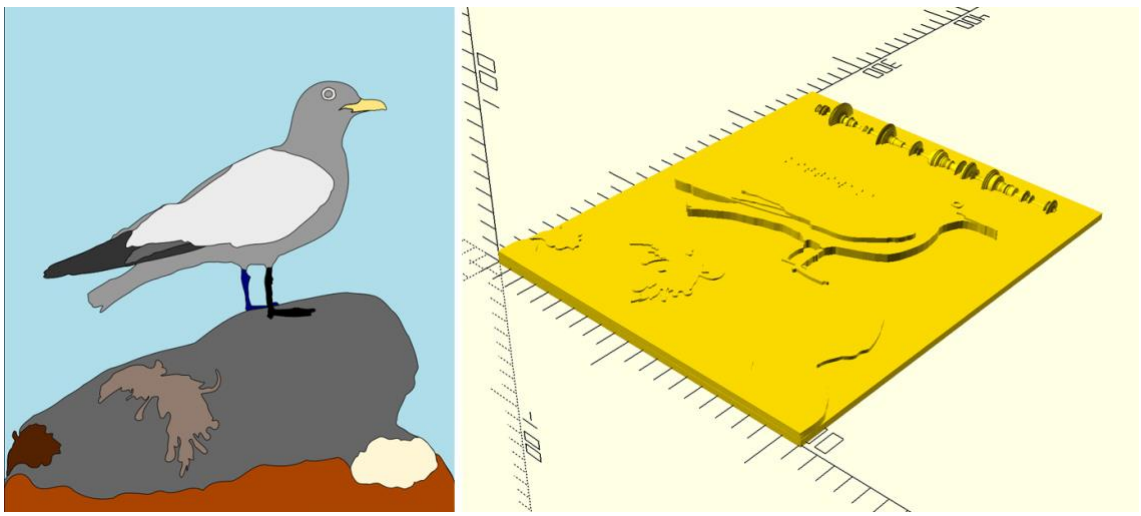


Figure 27: Vector representation of the diorama (left) and 3D relief in CAD software (right).

Consequently, a Computer-aided design (CAD) software (OpenSCAD) was used to assign suitable heights for each contour shape (fig. 27). Editing in CAD software was done with

training and support from colleagues at the Digitisation Lab of the UoB (see also 1.8 for the received support). Some of the key design requirements that were taken into consideration during this phase are:

- Size reduction: The relief is a smaller version of the original diorama. The original dimensions of the display (excluding the frame) are 510*415mm. The size of the relief is 250*210mm. There is a reduction of approximately 50% which was partly determined by the capacity of the printer's deposition bed and research from Oouchi et al. (2010), who experimented with reduced versions of Mona Lisa and recorded users' feedback about painting recognition. Their research indicated that the adopted size reduction would be safe to allow recognition of the relief's features.
- Elevations: Most individual shapes on the relief (apart from the soundwave and the bird's body) have a difference in height of 1mm with respect to the area where they "sit". Even though there is research indicating that recognition of map symbols can occur at lower elevations, this choice was partly determined by consideration of guidelines about minimum heights for symbol recognition (BrailleAuthority.org, 2008; Gual and Puyuelo, 2014; Jehoel et al., 2009). The body of the kittiwake has a height of 5mm as the purpose was to emphasise this particular shape to improve recognition. Research on raised-line images discusses the importance of emphasising objects' boundaries/edges in order to facilitate recognition (Krufka and Barner, 2006). In addition, the eyes of the bird have been designed to be concave, as this is a universal reference point for visually impaired people (Hewitt, 2015).
- Braille label: The label in Braille reads *kittiwake* and it has been designed based on specific guidelines to determine distance between symbols, distance between dots on the same cell, dot base diameter and dot heights (BrailleAuthority.org, 2008). Also, the label is placed at a distance of around 8mm away from the kittiwake following guidelines from the *Braille Authority of North America* (2011).
- Colour: Even though colour is important for some visually impaired groups, colour was not included in the relief due to: instability of available materials (most are UV sensitive and change colour after some months); different colour recognition abilities depending on the type of impairment; limited capabilities for colour transferability on the flat surfaces of the relief; concealment of relevant processes, as many

companies and researchers do not reveal the processes to add colour in fabricated artefacts (Hewitt, 2015).

- Texture: Texture information is not included in the relief mostly due to the lack of a satisfactory solution to represent feathers. Furthermore, depth information within individual elements was not considered due to the lack of conclusive evidence to support clear design guidelines. For this reason and in order to maintain a level of coherence, possible solutions to represent the shape of pebbles or rock, have not been deployed.
- Soundwave: The relief also includes a 3D representation of the soundwave of the kittiwake's call. This was created by tracing the soundwave into a 2D shape. The 2D shape was imported into CAD software and span around one of its axes to form a solid with rotational symmetry.

Figure 28: 3D model of the diorama (left) and 3D printed relief (right).

The resulting 3D model is shown in fig. 28 (left). The relief (fig. 28 right) was printed in a Stratasys Fortus 250mc 3D printer using ABS material.

5.3.3.2 Development of audio

The audio description of the relief was written as a text and then recorded in sound recording software. When creating a description that aims at supporting visually impaired audiences it is crucial to take into consideration a set of guidelines that structure auditive information in

a comprehensible way. Such description can be divided in two phases. The first phase refers to *picture description* and includes: information about the general view/representation, location of each element, description and summarising facts. The second phase is about *picture guidance* and includes: a presentation of the tactile object, general guidance through it and details with respect to its elements (Eriksson, 1999).

Hence, the 3D relief audio was structured in sections: a. Diorama display - general introduction (introduction, general view/representation); b. Relief - general introduction (introduction, general view/representation, location of each element, general description); c. Relief - in detail (guidance, presentation of each element: position, form, direction, materials, colours), plus the sound of kittiwake's call; d. Kittiwake - general information (summary). The audio, apart from taking into account the above set of guidelines, incorporated suggestions from professionals after attending an Audio description training session at the Booth Museum by the company Vocal Eyes in June 2017. The final description was also reviewed by the curators of the Booth museum (the description can be found in Appendix B).

5.3.3.3 Development of mobile application

Mobile devices, which are now part of everyday life, can provide a variety of contextual information relevant to a user, such as position, movement or proximity; or relevant to the environment, such as light, temperature and humidity. These technologies are part of the *Internet of Things*[40], allowing people and things to be connected at anytime and anywhere.

Context-aware technologies are increasingly found in museums. By adapting content to context, these technologies promise more engaging and personalised experiences. Systems react to visitor preferences, movements, directions, proximity and other actions and provide content to suit their needs and present information about the artefacts on display accordingly. Chou et al. (2015) and Seidenari et al. (2017) present various context-aware museum tour guides that use information related to the personal context of individual

[40] The Internet of Things as conceived by Ashton (2009) is the idea of creating a system where objects collect and exchange information without the need of human input. In this way, data and communication become interwoven in our environment in a seamless way.

visitors. In these examples, the context is mostly used to adjust systems' recommendations and support visitors to learn and enjoy their museum visit.

Figure 29: The interface of the mobile application.

For the Booth Museum study, a mobile application was developed to provide guidance on how to navigate the relief as well as information about the kittiwake and its call. An important requirement was to have a context-aware system that would alert and guide the visitor completely hands-free (when approaching the display and relief), without interfering with the user's tactile experience. The mobile application, using context-aware technology by deploying *Estimote's* proximity *beacons* (Estimote, n.d.), was developed by colleagues at the Digitisation Lab of the UoB (see also 1.8 for the received support). Beacons constitute a class of Bluetooth Low Energy devices which broadcast their identifier to nearby portable electronic devices. Most modern smartphones constantly scan for these signals, when location services functions are on. For the mobile application a *beacon ranging* functionality was deployed to measure the distance between the user's smartphone and the relief with the beacon. Hence, the application would only trigger the audio when the user was at an arm's distance from the relief.

The user interface of the application is very basic (fig. 29). It displays an image of the kittiwake diorama and provides buttons to pause, play and start again the audio description. The application was developed using the Android Operating System (OS) by deploying the Android and Estimote Software Development Kit (SDK).

5.3.4 Management, resources and technology

The case study has been the product of collaboration between the researcher, stakeholders at the RPM and colleagues at the UoB.

The production of relief itself and the complementing audio application resulted from the combined efforts of the author of this thesis and colleagues at the university -particularly the Digitisation Lab- who have assisted with the mesh editing in OpenScad and production of the context-aware mobile application. Technicians at the 3D printing suite of the UoB fabricated the relief and post-processing was done by the researcher. All assets were produced with budget coming from the School of CEM at the UoB.

With respect to digital fabrication, there have not been found in literature other examples of environmental dioramas presented in the form of a 3D printed relief. The advantage of the 3D printed kittiwake relief, in contrast to widely used 2D tactile maps and graphics (which deploy symbols such as lines, points and textured areas), is that it conveys volume and perspective; thus, depth and distance through a layered representation. Traditional methods to produce raised graphics, such as microencapsulation (swell paper reacting to heat) and thermoforming (thermoplastic film that acquires shape through heating and pressure) would not provide the flexibility that 3D editing and printing offer over “accuracy” nor the control over geometry, including limitless control of elevations (Cazorla and Macia, 2013; Gual and Puyuelo, 2014).

5.3.5 Overall study set up, preparations and processes

As explained in the beginning of this chapter, the development of each case study followed the approach of exhibition design, while deploying the RXF framework which can help with the design of replicas and their incorporation in CH experiences (see 8.4.2.1). Hence, a variety of intellectual and practical processes outline the preparation and set-up of the case study. These included:

- **Ideation and concept development:** A wealth of input coming from colleagues in academia, museum professionals and stakeholders (in RPM and beyond), audiences (e.g. visiting exhibitions and taking part in events), literature research, and organisations' official documents (e.g. audience development plans) were valuable in order to form the initial ideas for the case study with visually impaired audiences.
- **Resources:** At the initial stages of the case study available resources were examined in terms of digitisation equipment (camera, filters, tripods, fabric, light stands); software; technical support (digitisation lab, 3D printing suite); digital fabrication (e.g. available 3D printers and their features); mobile phone devices; beacons; camera and audio recorders for the trials; available budget; and access to museum, its collection and audiences.
- **Museum/collection/artefact selection:** Based on initial ideation and due to its participation in the *Sensing Culture* project the Booth museum was chosen. Through discussions with RPM's stakeholders (e.g. outreach officer, curators, disability advisor) and by examining through museum walks the space, distribution of exhibits within it and the available interpretative media, the collection of dioramas was selected to work with (as it is the least accessible for people with sight impairment). Consecutive visits facilitated the selection of the display, which is a portable kittiwake diorama in order to be able to experiment with the digital acquisition and data collection processes inside/outside of the museum.
- **Audience selection:** Visually impaired people were selected as the target audience, due to RPM's audience development plans, the desire to make Booth's dioramas accessible to people with sight impairment, the participation of the museum in the *Sensing Culture* project and finally the topic of the research, as such audiences seem to benefit the most from tactile experiences with the involvement of digitally fabricated replicas. Access to the target audience was granted by the RPM, the Blind Veterans and the CERB officers.
- **Replica development:** 2D acquisition with a DSLR camera by using a polarising filter and tilting the camera was done to get the raster image of the diorama. Thick fabric opposite the display was used to avoid reflections. Then, processing and simplification were done in vector graphics software and further editing in CAD software to assign heights. The relief was finally 3D printed in ABS.

- **Media development:** Audio information was developed in order to facilitate the exploration of the relief by visually impaired users. The audio was structured following literature guidelines and guidance that was provided to the researcher through an audio description training session at the Booth museum (see 5.3.3.2). The text was first written and then audio recorded and processed at the UoB.
- **Application development:** A context aware application was developed using the Android Operating System by deploying the Android and Estimote Software Development Kit. *Estimote's* proximity beacons were used for the application and tested multiple times with the application running in android mobile phones (before the trial sessions with users), which were borrowed by the IT department of the UoB.
- **Evaluation:** The evaluation was built upon the methodology and methods described in Chapter 3. To facilitate data collection, guidance sheets, information sheets and consent forms were printed and read to the participants. Participants and a witness signed the forms before participating in the research. Apart from the printed forms, the equipment/resources used for the evaluation sessions included: the portable kittiwake diorama (or printed poster of it in CERB), camera and tripod to capture video recordings of the sessions, the 3D printed relief, proximity beacon, mobile phones with the audio application (phones with lanyards to carry around the neck), and audio recorders. Users were video recorded while interacting with the relief and notes were kept in the observation protocol. Video recordings were later transcribed to facilitate data analysis. Few users did not wish to be video recorded and hence only handwritten notes were kept on the observation sheets. Questionnaires were also read to participants and interviews were audio recorded and then transcribed.
- **Pilot study and data collection:** The pilot study took place at the Booth museum. The setup comprised the display with the kittiwake on a table, while the relief with the beacon was placed in front of the display. A chair was placed in front of the table to allow users to sit and test the relief and application. The pilot revealed that trials should have been organised separately from the informative session on 3D printing to avoid bias and participants' discomfort (as they had to leave the session to do the trial and come back). Also, interviews would work better than a focus group and clear guidance was needed to clarify the trial processes. Lastly, it was decided to deploy hedonic/satisfaction measurement for the sensorial properties of the relief instead

of magnitude estimation. Consecutive data collection sessions took place in the Blind Veterans' premises in Brighton and the CERB in Greece.

- **Data processing and analysis:** Quantitative and qualitative data were transcribed and analysed as described in 3.4.11.

5.4 Evaluation

5.4.1 Data collection methods

This first case study (as all case studies) involves analysis of real life subjects, situations and relations, in highly contextual experiences that are examined by adopting the case studies' approach (Denscombe, 2007; Yin, 2009) (see Chapter 3). The data collection methods to gather evidence and address the research questions through this case study were considered as appropriate for interdisciplinary research, as they were not restrictive in terms of using quantitative and qualitative data. Moreover, in order to provide as much authenticity and comprehensiveness as it was possible (Lindauer, 2005) and triangulate data, the collection of evidence included:

- video recordings;
- observation notes;
- short questionnaires;
- focus group discussion and individual interviews.

Copies of the observation protocol, a sample of a transcribed observation, the questionnaire sheet, the interview sheet along with a sample of a transcribed interview for the first case study can be found in Appendix B. Further information about the data collection methods has been detailed in 3.4.5.

5.4.2 Pilot study

The pilot case study was carried out at the Booth Museum in summer 2017. The pilot study was part of a set of activities for the *Sensing Culture* (Van Hesteren, 2016) project, that visually impaired people were invited to attend. The day was structured to collect feedback about several applications that the Booth's officers had prototyped, with the purpose of making the contents and the setup of the museum more accessible for the visually impaired.

A session about 3D printing was programmed for the visually impaired participants in the afternoon. In the beginning of the session the scope of the research was introduced, and all

relevant information sheets and consent forms were provided. While the session about 3D printing lasted (showcasing 3D printed objects, giving an overview of the technology and demonstrating 3D printing in action), each participant was invited to a separate room of the museum, where the trials of the 3D relief and mobile application took place. All participants were guided to this quiet room along with their accompanying person. There, they were given a mobile phone with a lanyard to carry around the neck, while having their hands free for exploration. When participants approached the relief and diorama that were placed on a table, the beacon triggered the audio description (fig. 30). After the exploration, the participants were asked to respond to a questionnaire about the features of the relief and the experience. As soon as all participants had finished with the individual sessions, a focus group took place in the main activities/discussion room.

Figure 30: The setup of the trials for the pilot case study and participant exploring the 3D relief with the support of the mobile application.

In the pilot study, four partially sighted and blind people participated. Half of the participants were men and half women. One recognised himself as blind and the rest as partially sighted. Most participants had some level of sight or memory of sight (those with total blindness). Three participants were aged 60 years plus and were all using hearing aids. These were members of the *Blind Veterans* charity, which provides training and support to visually impaired people who have served in the *Armed Forces* or *National Services*. Another participant works as an artist and disability adviser.

5.4.2.1 Lessons learned

The pilot study constituted a very useful initial step in the evaluation process. On the pilot study day, people seemed to enjoy the session about 3D printing and valuable data were

collected through the trialling of the application. The pilot also revealed some key points that were consequently revised for further data collection sessions. One of the issues that came up was that people did not like having to leave the 3D printing session to trial the application and then come back. Nevertheless, it was not possible to deliver the session to all participants and then do the individual trials due to the schedule of the day as decided by the museum's officers and hence time constraints. In addition, one of the participants (or better his accompanying person) shared his opinion about the trial when coming back to the main room, introducing a certain amount of prejudice about the whole experience. In following data collection sessions, when time constraints were not that tight, the 3D printing session took place before trials. Individual interviews were opted after the pilot day in order to better capture each responder's opinions without external interventions.

Another issue that came up on the pilot day was that people (as they were of a certain age) could not easily understand the process of trials, even though this was explained to them at the beginning of the group session. Therefore, it was decided that they needed better instructions and support in the beginning of each trial on an individual basis. For the consecutive data collection sessions, a guidance sheet was prepared (see Appendix B) and detailed instructions were given to participants before each trial.

With respect to the application in the pilot study, some participants found the audio description fast. Hence, the audio was modified to follow a slower pace and restructured for consequent trial sessions. Lastly, as a result of the pilot study, some modifications were made in the questionnaire in order to improve the collection and analysis of data. For instance, in the *Visitor background* section of the questionnaire there was a question about the educational level of the participants. People found it difficult to respond to the question and seemed uncomfortable with it. So, it was decided to remove it and omit such data. Moreover, in the section *Object features and mobile application* the introductory question was changed from *"On a rating scale from 1 to 5 how would you rate the following features of the relief?"* to *"How well do you think that this relief works for people like you? On a rating scale from 1 to 5 how satisfied are you with the following features of the relief?".* The improved, re-phrased question provided further reference (the relief with respect to you and people like you) and details on how to rate the relief (satisfaction measurement). Techniques, such as these, to project one's thoughts in order to increase participants' comfort level and facilitate

responding are documented in museum evaluation literature (Diamond et al., 2016, pp. 72–73). As a result, a small part of the data that were collected to rate the relief during the pilot study -rating *magnitude estimation* instead of *hedonic/satisfaction measurement* for subjective sensorial properties- had to be discarded. All consecutive data acquisitions measured satisfaction on a rating scale.

5.4.3 Further collection of data

After the pilot study at the *Booth Museum*, more data were collected in October 2017, during a visit to the *Blind Veterans'* premises in Ovingdean (Brighton), and in February 2019 at the premises of the *Centre for the Education and Rehabilitation for the Blind* (CERB) in Thessaloniki, Greece[41].

5.5 Findings

The data that are analysed in the following sections reflect the opinions, ideas and overall evaluation of the experience from twenty-five (25) participants[42].

5.5.1 Personal context

Twenty-five (25) totally blind or partially sighted visitors explored the 3D relief with the support of the mobile audio context-aware application. All visitors were observed (also video recorded) and then they were asked to fill in questionnaires and respond to questions during semi-structured focus group discussion and individual interviews. Ten (10) participants were women, amongst them five (5) were totally blind and five (5) were partially sighted. Men participants were fifteen (15) and amongst them five (5) were partially sighted and ten (10) blind (fig. 31). Ten (10) blind participants had previous sight memory and five (5) did not have any visual memory (congenitally blind). Fourteen participants (14) were Braille readers.

[41] All content and sheets were translated in Greek for the data collection in Greece. Copies can be found in Appendix B.

[42] With the exception of some data from the pilot study that were discarded due to changes in the questionnaire format (responses from four participants about the weight, texture, temperature, durability ratings of relief). In these four ratings, there will only be responses from twenty-one (21) participants.

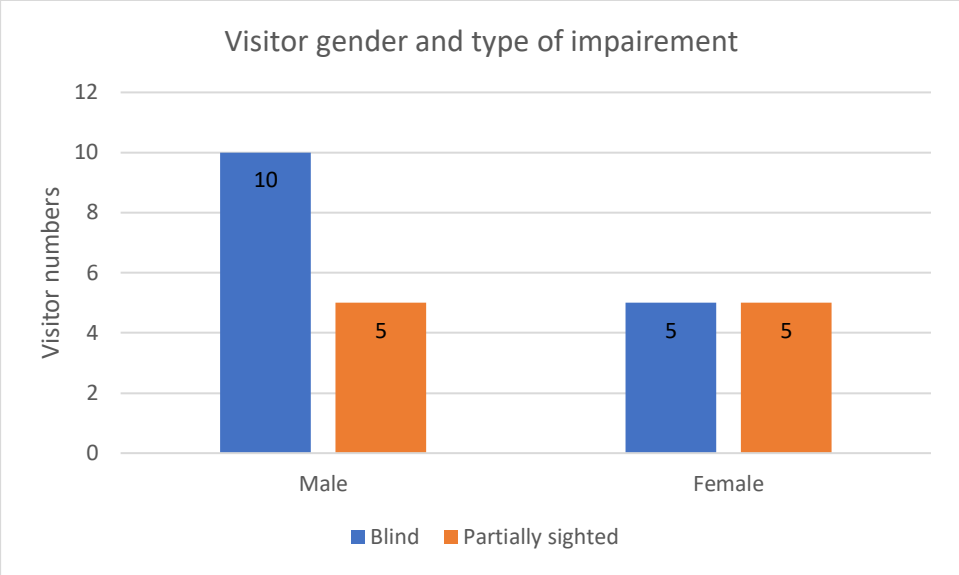


Figure 31: Female and male visitors and type of visual impairment.

With respect to visitors' age, a good range of ages is presented in the research with most users belonging to the 60+ and the 25-39 group (fig. 32). The majority of older users came from the Blind Veterans charity, were younger members constitute a "valuable minority" as one participant stated. Younger participants mostly came from CERB, as it also works as an educational and vocational qualification centre in northern Greece.

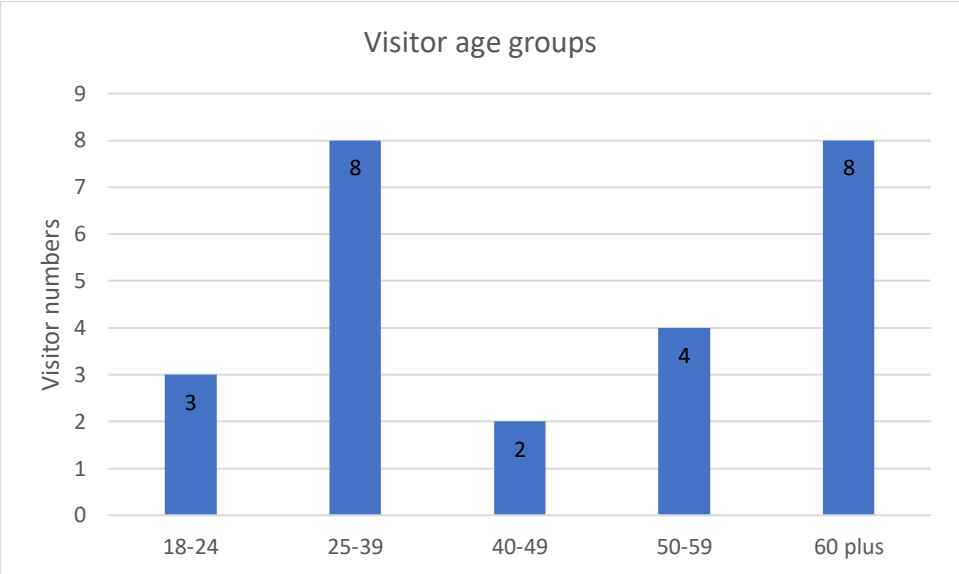


Figure 32: Visitors' age groups.

All participants, apart from one, came from a white ethnic background. All participants from Britain live in the south part of the country. The participant who is located the closest to the museum lives two (2) miles away from it and the farthest one lives one hundred thirty-five (135) miles away. The mean distance of the participants' residence in Britain is 31.5 miles

from the museum. The rest of the participants came from Greece and hence residence data were not taken in relation to the Booth Museum.

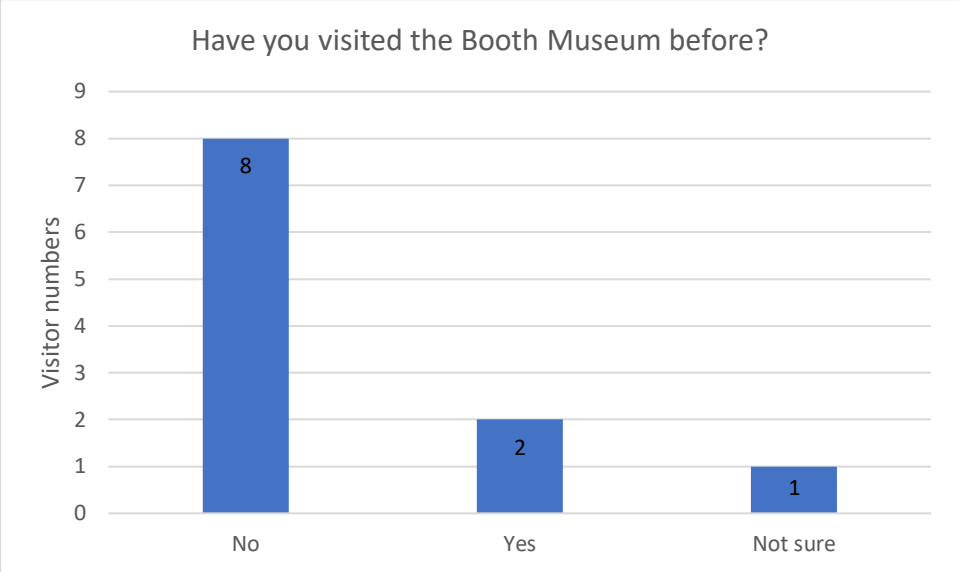


Figure 33: Previous visits to the museum (responses from the participants in Britain).

Participants had different levels of knowledge/experience and expectations/motivations with regards to museum visits, interaction with objects and background information. Only two (2) of the participants in Britain had visited the Booth museum in the past (fig. 33), even though eight (8) of them live less than fifteen (15) miles away from it. In order to find out about Greek participants' previous knowledge, people were asked whether they had visited a natural history museum in the past. Amongst the fourteen (14) participants from CERB, twelve (12) had visited a natural history museum, even though there is not a natural history museum in the city where CERB is based. Hence, they had travelled to visit such museum elsewhere.

Most of the participants' past or current occupation was not related to CH either. However, one of them had experience working in the arts, one in heritage (as collections' officer) and two more work as teachers for blind children.

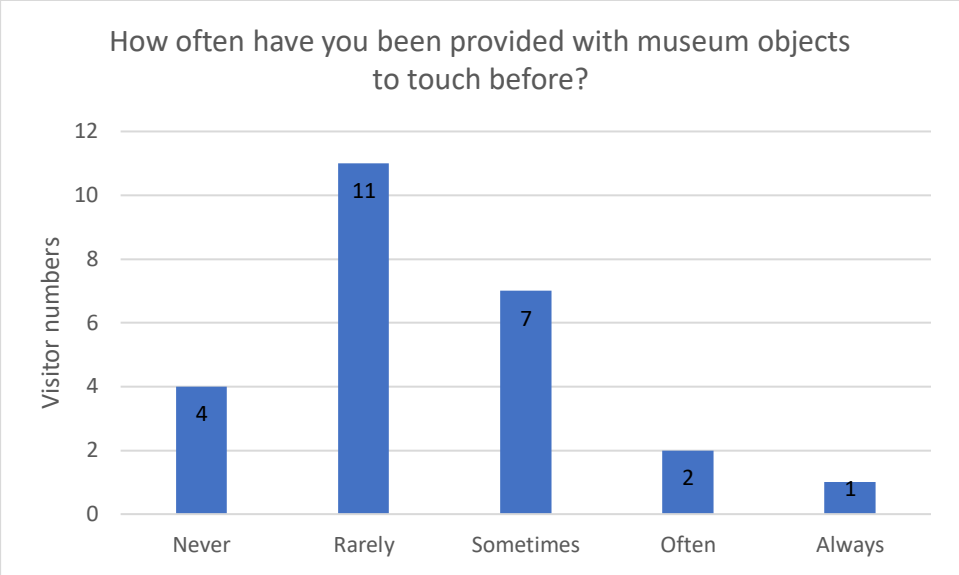


Figure 34: Previous experience in touching museum objects.

People had limited experience in touching objects in museums (fig. 34). Such finding is not surprising as touch had almost been "banned" for many years from CH contexts and only in the last decades CH organisations started integrating touch as a rather fundamental part to experience art and heritage for visually impaired and other groups of audiences (see section 2.5.2). Amongst the three participants who have had regular opportunities to touch objects, one was the blind children's teacher and the other one was the collections' officer. Thus, both can be considered as enjoying "privileged institutional" access to artefacts.

Previous experience in using technology in museums was balanced (fig. 35). Twelve (12) participants had never used technology in museums to support their experience and thirteen (13) of them had used IT in CH settings. Such finding might be related to age, as ten (10) out of the thirteen (13) who had previous experience with technology in museums and CH events belonged to ages between 18-49 years old and thus can be more technology-literate.

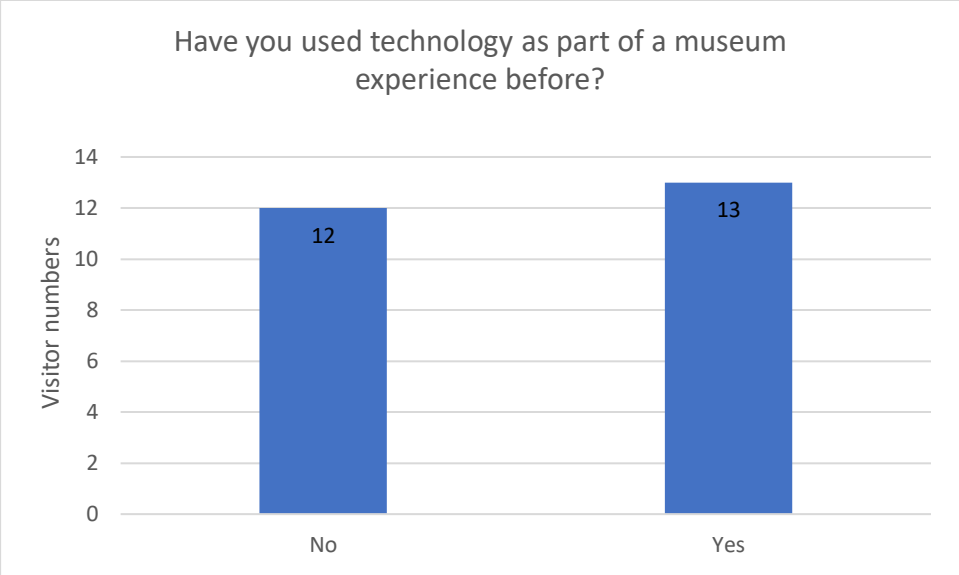


Figure 35: Previous experience in using IT in museums.

In terms of people's expectations, the intention was to find out what people were expecting or were looking forward to doing during the visit/session. Four main tendencies have been recognised based on participants' responses as demonstrated in table 12 (from strongest to weakest): feedback session; no expectation/not sure about it; find out and learn; tactile experience. Most comments can be explained as the result of a rather organised activity (not necessarily self-motivated) in a museum (Booth) or institute (Blind Veterans, CERB). It is very rare to find in CH research and beyond examples of feedback collection from blind and partially sighted participants outside of an "institutional" framework. Such remark highlights the still existing societal incapacity to provide access to infrastructures for this group of people on a regular basis outside of organised environments or events. Therefore, "outings" to museums and participation in relevant CH activities might still impose physical and cognitive barriers for people with visual or other kind of disability.

Expectations (tendencies)	Participants	Representative people's comments
Tactile experience	1	*"I expected that the presentation would be different and that we wouldn't find glass displays. We have got to be able to touch."*
Feedback session	17	*"'I had a vague idea of what we have done here."* *"What it was. An experience using an app device."* *"Touching a relief while hearing the audio description of a box in front of me."*

Expectations (tendencies)	Participants	Representative people's comments
No expectation / Not sure about it	5	*"I didn't really know what to expect."* *"I had no idea."*
Find out and learn	2	*"I am always interested in what is going on."* *"I am interested in 3D printing."*

Table 12: Tendencies in participants' expectations.

Quite similar are the results when examining people's interests concerning the contents or collections of the Booth Museum or natural history museums in general. Five tendencies were noted as demonstrated in table 13 (from strongest to weakest): no specific interest; general collection/natural specimens; fossils and mammals; whatever is accessible; bird collection (dioramas). The most striking comments from participants here are related to the fact that accessibility to heritage information would automatically make things interesting. As two of the participants noted: *"If anything makes it accessible, it would encourage me to be interested"* and *"I am interested in whatever is accessible"*.

Interest	Participants
General collection/natural specimens	8
Bird collection (dioramas)	1
No specific interest	11
Fossils and mammals	3
Whatever is accessible	2

Table 13: Tendencies in participants' interests.

On the other hand, for many participants visiting a museum or taking part in an event is an opportunity to meet with people, socialise and enjoy an activity that brings a change to their daily routines, without necessarily having a specific interest in a collection.

5.5.2 Social context

This section addresses and analyses the social context of the experience of the 3D relief with the use of the mobile application. Taking into account the parameters as described in the RXF (section 4.3), the social context examines first the composition of each visit. As already mentioned, data collection opportunities were of a "scheduled" nature. The place of the data collection dictated whether people came accompanied or not. At the Booth Museum, three (3) out of the four (4) participants had a volunteer or a helper who came with them, whereas

at the Blind Veterans' institute and the CERB in Greece all participants were on their own. In two cases, where the participants had their helper along at the Booth museum, it was observed that the helper occasionally was in charge or tried to take over the situation; blind or visually impaired people were relying on them in many instances during the exploration of the relief and later when filling in the questionnaire. As for the type of interactions between the participants and helpers or participants and the researcher (or occasionally self-expressions of the users), these were of verbal or physical nature. Verbal interactions included: guidance to the participant to sit and help find the relief on the table; motivation to touch the relief; request for verbal confirmation when the users successfully located the contents of the relief; verbal confirmations to themselves *("yes!", "right", "that's it!"*) when the users located the contents of the relief; expressions of opinion about the experiences directed to the helper or the researcher (*"very good"*). Physical interactions included: physical touch (from helper) in the form of motivation to interact with the relief; nods from the participant to ask for the helper's confirmation or assistance; smiling/tapping with fingers when locating the elements of the relief.

The social environment in all cases was not crowded as trials took place in rooms that were booked in advance and hence could accommodate the blind or visually impaired participant and his/her helper (when present). Occasionally, there was some noise coming from people passing by or discussing outside the rooms and some minor interruptions. When the participants had hearing aids, external noise made listening to the audio description and focusing on it more difficult, but the disturbance usually lasted for a few of seconds.

5.5.3 Physical context

The physical context of the experience refers, in the first instance, to the CH object itself, hence the actual diorama which was present and placed behind the 3D printed relief in all data collection sessions. In Greece, a full-size printed poster of the diorama was placed opposite the participants, as it was not possible to transfer the diorama abroad. Then, the location/setting and atmosphere of the place, where the experience takes place, are examined. As already mentioned, data collection took place in rooms that were booked for the trials. At the Booth museum, a small room without natural light serving as storage space was provided. All around there were shelves with covered and uncovered dioramas. The particular smell of the Booth Museum due to the existence of many specimens was noticeable

everywhere. At the premises of the Blind Veterans, the audio library room and a kitchen training room were provided for the trials. Both had natural light coming in and were located in busy areas of the building. The audio library room was not noisy, whereas the kitchen training room was occasionally noisier. In CERB, the trials took place in the office of a staff member from the educational team of the institute. The room was very bright, but full due to the existence of many educational materials. Occasionally, there were noisy disruptions coming outside of the room that lasted for some seconds. People generally seemed more comfortable in the premises of the institutes for the visually impaired, as these were places they knew, whereas they were relying on other people to move around at the Booth museum. Thus, even though the museum might imply a more "original" experience in spatiotemporal terms, this comes with a trade-off, as people might not be fully confident in exploring exhibits and collections independently.

Apart from three (3) out of the four (4) participants who took part in the pilot study at the Booth, all the rest (21 participants) found the exhibit and the replica easily and they were attracted by it. Nonetheless, this can be related to the fact that clearer instructions were given to them, as a guidance sheet was prepared after the pilot study.

As far as it concerns the interpretative means, most people noticed the Braille label with the word "kittiwake" on the 3D relief. Amongst the fifteen (15) Braille readers, fourteen (14) read it easily and aloud, in most cases even before the description got to it and even though the label was written in English Braille (most were Greek users but knew how to read in English Braille). In general, the interpretative means that participants paid most attention to are presented in fig. 36. Most participants (17 out of the 25) paid attention both to the 3D relief and the audio description. Amongst them, the vast majority were blind (14 out of the 17 users). Five (5) participants explored all means (relief, audio and diorama display) at the same time. These had partial sight and occasionally turned to look at the display (and maybe corroborate information) when the audio description referred to it. One partially sighted participant looked at the image of the diorama on the mobile phone application, while listening to the audio and touching the relief. Another participant only focused on the audio and the diorama. This person, though, had enough partial sight and preferred looking at the real specimen in the display. The only participant who focused mostly on the audio, found it difficult to explore the relief by sound and touch simultaneously. This person had visual

memory and seemed that he had not acquired tactile skills at an early stage (due to age related blindness), which made the interaction with the relief difficult (Heller, 2002).

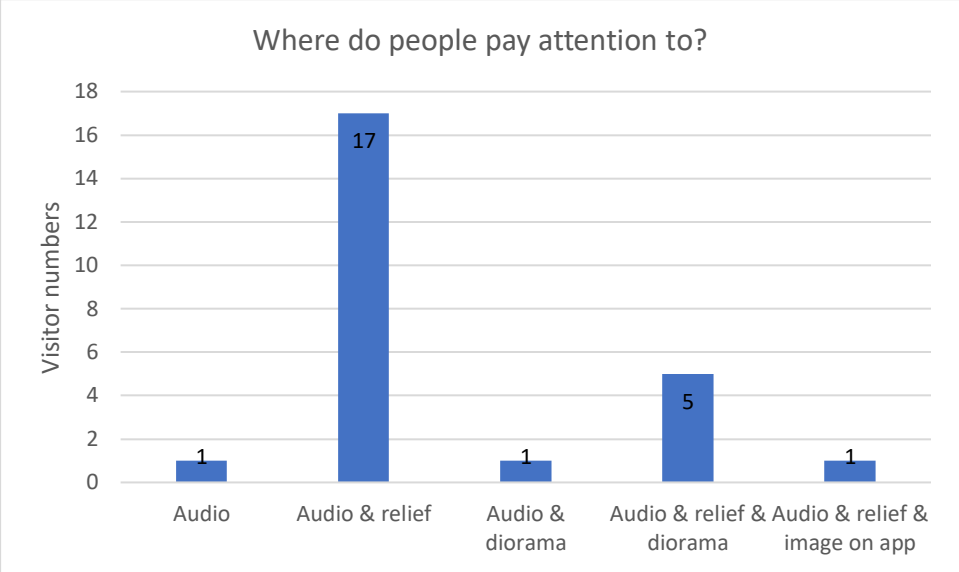


Figure 36: Interpretative media attracting people's attention.

Regarding the usability aspect of the experience, most people found it easy or very easy to use the application (fig. 37). However, mobile phones with the application running were given to the participants, so they did not have to download the app and activate it themselves. Providing devices to users was a necessary choice as it was not possible to know whether they had a smartphone and were able to download the app themselves. In addition, lending devices to visitors when coming to the front desk of a museum consists a common practice that could be deployed at the Booth museum too. Fewer participants, responding that the question was N/A or that the use of the application was neither difficult nor easy, found it difficult to rate the ease of use of the application, since they had not done much with it. Such remark might be related to some challenges in evaluating ubiquitous IT applications (see 3.4.4 and 4.4.2), as well as the fact that some participants were of an older age and were not familiar with the use of technology. Some further remarks about usability are related to certain functionalities for visually impaired people that were missing, such as voice reading and voice controls (this can be third party software installed on a mobile phone); locking the screen to active mode to prevent light from going off while the application is running. Also, occasionally there was some waiting when starting the audio description due to delays in the distance recognition between beacon and device. A last remark with respect to usability, when examining applications with visually impaired people, that is worth to mention refers

to the type of tests and measurements that are usually deployed in research. As some users noted, they were pleasantly surprised that the relief navigation did not include formal tasks (such as explicit tasks with identification of elements) or measurements (such as number of errors or time calculations); something that might demonstrate further research considerations when examining applications within "living experiences" for these audiences (see 3.4.4 and 4.4.2). As one of the participants noted: *"I believe that it is important not to get into a process of thinking/finding out what this is. You just enjoy learning about it."* and *"It isn't a test. We also learn something."*

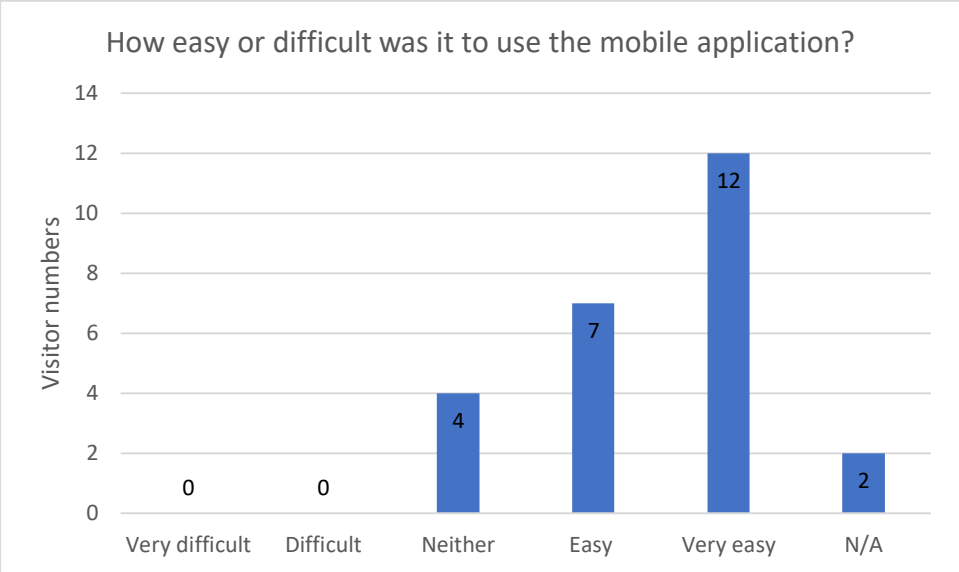


Figure 37: Usability evaluation by the participants.

The audio description was another element that people were asked to rate. Almost all of them (24 out of the 25 participants) were satisfied or very satisfied with the audio description (fig. 38). Just one participant rated the audio as neither satisfying nor unsatisfying. Some participants also commented positively about the inclusion of the actual kittiwake's call, as listening to it made the experience more interesting and complete. The soundwave was commented in various ways. Some participants could not understand its purpose and how to "interpret" it, even though there was guidance on the audio description about it. Other users found it "novel", "imaginative" and "interesting". Another participant commented on its material and noted that he would like it to have a more flexible/soft feeling.

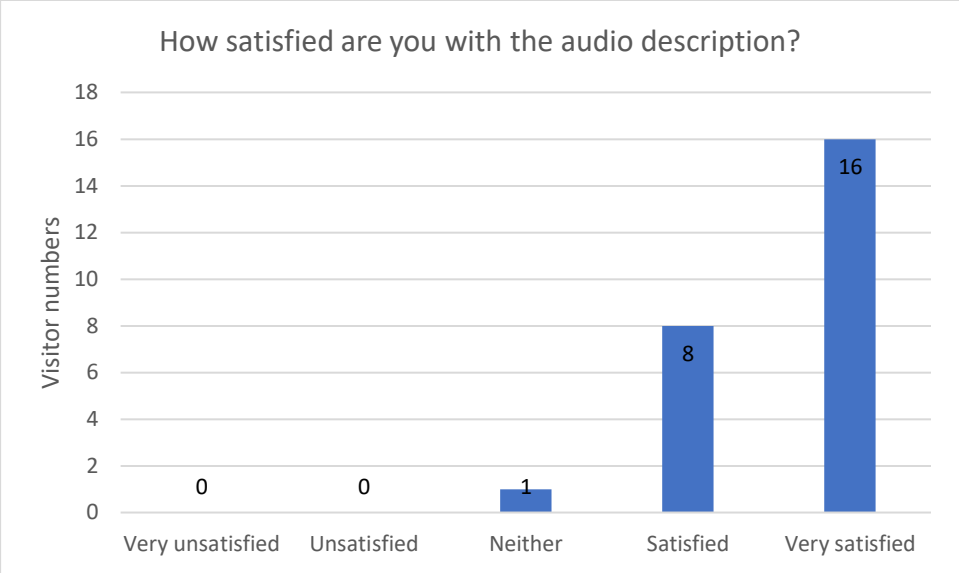


Figure 38: Audio description evaluation.

When evaluating the features of the relief people were asked to rate its subjective sensorial properties on a 5-point satisfaction rating scale (see 4.5.3.3 for sensorial properties measurement). Emphasis was given to the tactile properties of the relief as the audience consisted of people having limited or no sight. For sensitivity reasons, a general open-ended question about the visual appearance of the relief was also included in the questionnaire for those who had some comments about it. When finishing rating the tactile properties, people were questioned whether they would want any of the features of the relief to be changed if they did not like them. The following charts in fig. 39-44 present the evaluation of the properties of the relief.

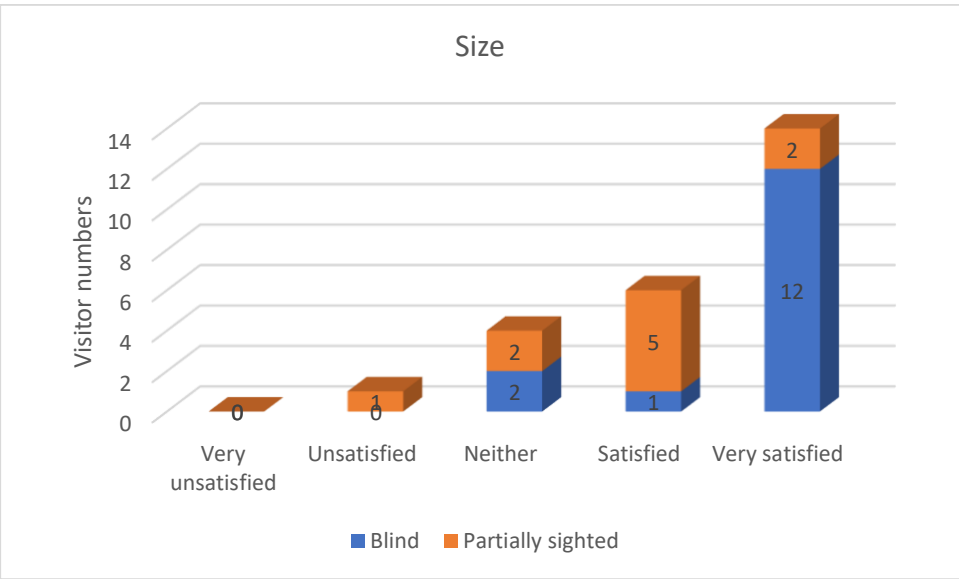


Figure 39: Rating of the subjective sensorial tactile property of size of the relief.

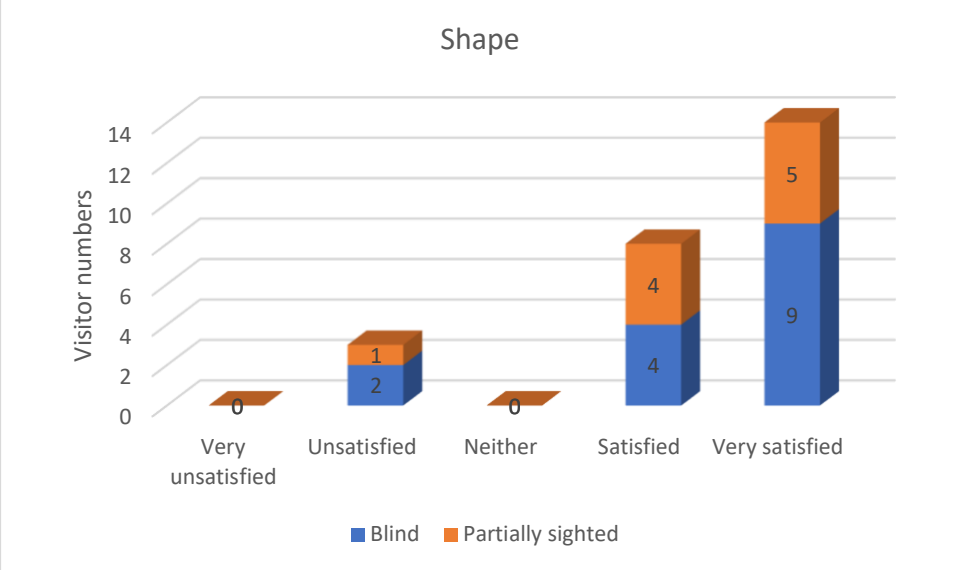


Figure 40: Rating of the subjective sensorial tactile property of shape of the relief.

Figure 41: Rating of the subjective sensorial tactile property of weight of the relief.

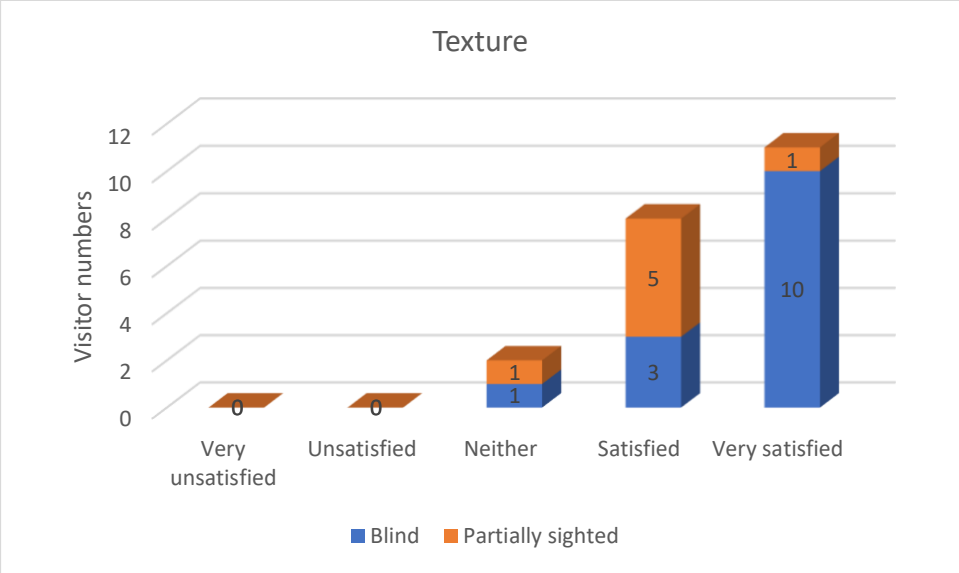


Figure 42: Rating of the subjective sensorial tactile property of texture of the relief.

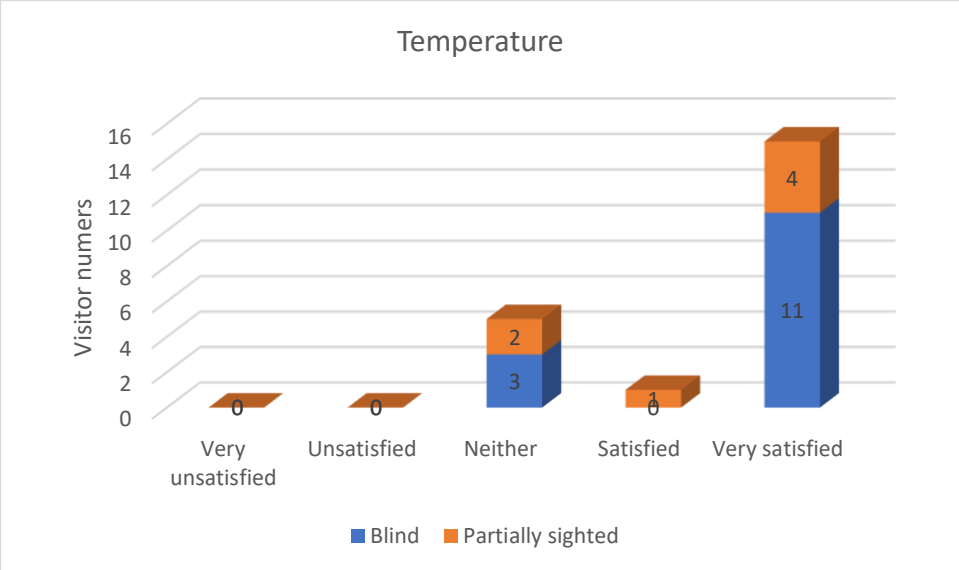


Figure 43: Rating of the subjective sensorial tactile property of temperature of the relief.

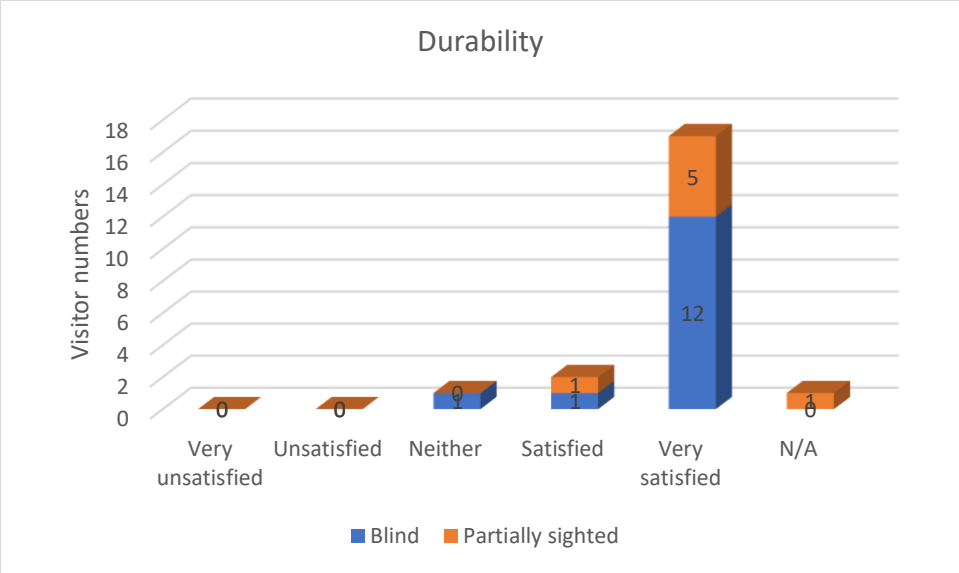


Figure 44: Rating of the subjective sensorial tactile property of durability of the relief.

Most partially sighted participants were "satisfied" or "very satisfied" (7 out of 10) with the size (fig. 39) of the 3D relief, whereas one was unsatisfied with it without providing any reason. Most blind people were "satisfied" or "very satisfied" with size (13 out of 15). The majority of both blind and partially sighted people were "satisfied" or "very satisfied" with the shape (fig. 40) of the relief. Three people (1 partially sighted and 2 blind) were "unsatisfied" with the shape of the relief: one of them found it difficult to follow the description and synchronise tactile with hearing skills; one found the shapes of the seaweeds difficult to distinguish; and the third one seems to have confused shapes with textures. When asked about possible changes on the shapes of the relief, some participants suggested that certain parts could be better differentiated from the rest of the relief; particularly, the whelk eggs that were not understood by everybody *("The ball of eggs could have been placed higher", "The whelk eggs could have been placed at a higher height"*). Another participant would want the soundwave disks and their height distinction to be clearer and another one wanted the wings of the kittiwake to have more details.

Most participants from both groups (19 blind and partially sighted) were "satisfied" or "very satisfied" with the weight (fig. 41) of the relief and commented later that it feels light and is very portable. One (partially sighted) user amongst the two who were "unsatisfied" with the weight later explained that he would want it to feel heavier. People's opinions about texture (fig. 42) varied from "neither satisfied nor unsatisfied" to "very satisfied". Nobody rated negatively the texture of the relief. However, when the participants were asked about

improvements with respect to texture they suggested: having different textures; having realistic textures for the seaweeds; having a different texture on the wings; using lines and dots on the seaweed and ball of whelk eggs to differentiate them, without exaggerating though as this would confuse people; and having a softer texture/material for the soundwave. As for the temperature (fig. 43) of the relief when touching it, most participants were "very satisfied" (15) or "satisfied" (1) with it and some preferred to stay neutral (5). Generally, the question about temperature was considered somehow unusual and, in many instances, people found it difficult to rate it (reflected in neutral responses and surprise of participants). Durability (fig. 44) constituted another rather unusual question and while most users (17) from both groups rated the relief's material strength as "very satisfying", there was a partially sighted user who could not rate it at all. The only user who was "neither satisfied nor unsatisfied" with durability, stated that he feels the relief can easily break.

Finally, as far as it concerns the visual properties of the relief, participants made a variety of comments that seem to depend on the type of visual disability of each user. Some could only recognise the outlines of shapes; one could only distinguish the rectangular shape of the relief; and one commented that he liked that the relief was not shiny. With regards to improvements, the eight (8) participants who suggested that the relief should have colours (one suggesting black parts instead of vibrant colours) were all partially sighted, plus two (2) blind participants who mentioned that colours would be useful for partially sighted people. One participant pointed out that a large print label apart from the Braille would be useful.

5.5.4 The expression - perception of the experience

This section is dedicated to the expression and perception of the experience as described in section 4.4 of this thesis. First, the section examines all sources of qualitative data (focus group, interviews, open-ended questionnaire questions and observations) and then follows a mixed approach to analyse them (see 3.4.11). Therefore, the analysis is done deductively to record people's feedback under the five themes of the RXF (*awareness/knowledge, engagement/interest, attitudes, skills, behaviours*) while allowing other themes to emerge in an inductive way. Data sheets and classifications, as demonstrated in examples provided by the *Arts Council* evaluation framework (Arts Council England, 2014a), have been very useful to draw ideas during this process. In coding, inevitably, there is a certain level of overlapping as some of the participants' responses were falling under more than one themes.

5.5.4.1 Awareness/knowledge

Data reflecting awareness, knowledge and understanding as effects of the experience with the relief and the audio application came from the questionnaire responses and the focus group/interview discussions. During the interviews, people were asked if the experience helped them to discover more information about the exhibit and how did that happen. The main subthemes for awareness/knowledge are presented in table 14.

Theme: Awareness/knowledge	
Subthemes	**Quotes**
Awareness	*"I thought it was interesting to, to actually feel and understand how totally blind people can determine what they are like."* *"Many congenitally blind -I am not congenitally blind, I got 'transferred' at the age of 15- have a very odd perception about birds. Completely. And when they touch a bird, a complete reversal of the idea that they had in mind happens."* *"And it might well work for someone who hasn't got any concept of scale or hasn't got any sight and wanted to have a specific sense of this feeling."*
Making sense of something/broaden understanding	*"…it gives me a chance to feel around to see what is going on and with your description of course it makes it easier."* *"They allow us to see and understand at a very high percentage -I mean very close to reality- the objects that exist in the museum."* *"I was able to understand how the bird looks like through touch, its body, its wings and everything and also through the audio description."* *"And it might well work for someone who hasn't got any concept of scale or hasn't got any sight and wanted to have a specific sense of this feeling."* *"I like the bit where it played the sound, so that you could put the shape of the bird and the sound... Before the audio played, I guessed it was some form of seagull from the shape. So, it has broadened that."*
Difficulty in understanding/lack of learning	*"Because I find this very difficult you know."* *"Not really, no. (it did not help him to discover more information)."* *"I wanted to know which way to start from and I wanted to know what the curviness means (in soundwave)."* *"Also, when touching the eggs, I don't believe that a blind person could understand them. It is a piece of cake for us to understand that there is an element at a higher level, but someone could not understand these are eggs."*
Using previous knowledge/experience	*"…well I had a vague idea, because I've always lived by the sea. I was born in a seaside town and I lived in Brighton for 20 odd years. So, I'm quite aware of what seabirds are like gulls and what you have. But not the specific species. I didn't know about the actual bird itself."* *"I mean I live by the seaside, so kittiwakes and seabirds I understand, and it was just really lovely."*

Theme: Awareness/knowledge	
Subthemes	**Quotes**
	"When she said that these two were seaweeds, I could feel it because I know what seaweed looks like." *"I understand about soundwaves due to my background (engineer in radars)."*
Learning facts	*"I am surprised that during the winter they go to sea. I thought that only the penguins did that."* *"I didn't know at all that this three-legged kittiwake exists."*
Expand factual information	*"The only bit that wasn't mentioned in there, as we are in Sussex, was that there is kittiwakes on, if there is any left, on Seaford Edwards. It is an unusual place, as they are usually up in the North Sea and around Scotland and beyond."*

Table 14: Awareness/knowledge related to the experience of the 3D relief and audio application.

People's feedback in relation to knowledge and awareness ranges from making sense of the exhibit, to learning actual facts about it (details about it or even the existence of it) and deepening understanding about specific elements of the diorama or general knowledge about the species. One partially sighted interviewee said that through the experience he developed a better understanding (and thus awareness) about blind people's interaction with objects. Another blind participant, who works as a teacher and has memory of sight, noted how such applications could help congenitally blind people perceive how birds look.

Other participants used previous knowledge deriving from their professional background, past explorations or the place they live during the identification and learning process. Another person expanded factual information based on facts that he already knew about kittiwakes. Nonetheless, some people expressed a level of difficulty to perceive some contents of the relief (particularly the whelk eggs due to their peculiar shape) and the structure of information for unusual shapes (i.e. the soundwave representation) or simply stated that the experience did not help them to understand the exhibit better.

5.5.4.2 Engagement/interest

The level of engagement and the interest that participants demonstrated is witnessed by acts or comments related to emotions, feelings, enjoyment, fun, surprise and generally the creative and inspiring aspects of the experience.

Observational data with regards to engagement and interest are closely connected to people's skills as described in the following paragraphs (see about skills in 5.5.4.4). Thus, those

who were able to locate the elements on the relief often demonstrated a sense of joy (i.e. smiled or nodded) or expressed themselves with affirmation sounds (e.g. "yes!") whenever they identified a shape. Others looked surprised when listening to the kittiwake's call while touching the soundwave. The users who kept tuning in and out of the relief seemed to lose and find their interest, depending on the success of the identification process. Some were lost at certain times or indifferent but came back to the relief to engage with the exploration. Only one participant demonstrated a level of disappointment and seemed rather disconnected.

Further qualitative data from the discussions and the open-ended questions of the questionnaire provide more detailed information, which can be organised in basic subthemes under the theme of engagement and interest. During the interviews, participants were asked if they enjoyed anything in particular about the whole experience. All basic themes along with representative quotes are presented in the table below (table 15).

Theme: Engagement/interest	
Subthemes	**Quotes**
Using senses	*"...you were using three senses in a sense, because you are using your listening skills, your feeling skills and your vision. I was using all three. That was interesting."* *"There was a perfect combination of the haptic and the audio element."* *"I started trying to see through the haptic exploration of the relief."*
Desire for creative activity	*"Well I thought I was gonna come in and paint you see… But I would tell them to get somebody to paint them (she means create paintings of the displays)."*
Reminiscence/memory recall	*"I used to love birds, but unfortunately I can't see them now. And in my garden, I get all sorts of birds. But I can't see them, unless they are very close to me. They don't do that very often."* *"…with things like the Maritime Museum, where we were doing some... they actually taught us some of the crafts; and that was very tactile."* *"And also, I would like to make a remark, because I have seen some more reliefs in the past... that the representation of the third dimension is very good."*
Feelings	*"You almost felt that you are actually looking at the real thing."*
Enjoyment	*"I enjoyed the sound of what the bird made."* *"I liked the information, the information that was given."* *"The audio was very good and I thought that the audio took me around, took me on the right journey..."* *"I enjoyed the relief itself, because we are able to touch in museums."*

Theme: Engagement/interest	
Subthemes	**Quotes**
	"I believe that it is important not to get into a process of thinking/finding out what this is. You just enjoy learning about it."
Moderate/no interest	*"As I enjoy most things. I have just enjoyed it yes."* *"To me that doesn't do me any sort of thing, it didn't make me excited at all, but if it was a kittiwake and I could have felt it."* *"I didn't enjoy anything in particular."*
Surprise	*"The model of the bird and the bird itself. I think it is very pretty. And that is a kittiwake?"* *"I like the idea of actually doing the sound of the kittiwake that was on top. That is a really nice idea!"* *"I was impressed with the sound. These disks. It made me a big impression!"* *"It was very pleasant. And to be honest I wasn't expecting it."*
Imagination	*"And then to be able to do the description with the relief gave me an understanding of putting back into a shape, back into my mind. So basically, what I was able to do in the recesses of my mind, it was to imagine..."* *"It just… of sort put it back in a more 3D, even if it is only in my mind's imagination, you know..."* *"The fact that, beyond the elements that I was able to touch, it gave me some extras to help me imagine. I was able to imagine by combining the three elements: haptic, description and my imagination."* *"We would be able to "travel" to a world which is unknown to someone who cannot see."*
Exploration	*"The fact it took you through stage by stage, it didn't tell you go and explore, it took you through stage by stage, which I think was better, so the guidance of…"* *"'Yes, the fact that every detail was becoming very clear."* *"… I thought that the audio took me around, took me on the right journey from the bottom. You placed things correctly and I think that it is quite interesting using your kinaesthetic and your... you know…"*
Connection to past interest	*"And I love the idea of the tactile sound. It was just... But that comes because of my... basically because of my background in engineering."*

Table 15: Types of engagement with the experience of the 3D relief and audio application.

The above table provides an indication of the variety of types of engagement that the CH experience with the use of the 3D relief evoked. Users enjoyed the whole experience or mentioned specific aspects of it such as the background information, the audio description, the sound of the kittiwake and more. The imaginative effect of the experience was further noted by users, who were able to bring into their minds an "image" of the bird or "travel" to

unknown worlds. Similarly, other users felt surprise by encountering elements such as the relief itself and the sound of the bird.

Combining their senses was something that users appreciated and found interesting, while many emphasised the exploration that was enabled by the audio guidance. Two users perceived the experience in relation to past heritage explorations, while another expressed himself in a more emotional way and associated the experience with past memories. After all, connecting present enjoyment with past interests is one of the types of engagement demonstrating the power of associations with actual people's lives (Hein, 2004). However, the analysis of data also includes statements of people who did not particularly engage with the experience or desired another type of activity (e.g. a hands-on, artistic type of activity).

5.5.4.3 Attitudes

The attitudinal aspect of the experience encompasses the set of principles that every person has. Each experience reflects on people's existing "equipage"; adds on his/her values; might build a person's self-esteem; change his/her beliefs and attitudes towards people or things. To explore the attitudinal part of the experience participants were asked: a. about the value of having 3D printed objects available to visually impaired visitors in a museum; and b. whether similar experiences would change their opinion about accessibility to museums. Their answers highlighted attitudinal subthemes as presented in the table 16.

Theme: Attitudes	
Subthemes	**Quotes**
Opinions/values	*"The value is that we will also be able to understand the exhibits of the museum, whatever they are, paintings, statues, regardless of the type of object."* *"In the first instance, the value is that the museum recognises them (he means people with visual impairment) as human beings and not as humanoids."* *"Great importance. Because they allow us to have a complete haptic image of the content of exhibits."* *"It has a great value for me… It is different if you describe it and I just remember pictures and different if I can touch and I am able to understand by myself…"*
Self-confidence/freedom	*"It gives me much more freedom of the feeling of being part of the real world."*

Theme: Attitudes	
Subthemes	**Quotes**
	"It is different if you describe it and I just remember pictures and different if I can touch and I am able to understand by myself its position or the way that a painter might have chosen to depict it or anything similar…" *"Even though I go to museums often, the navigation would be easier. I wouldn't need a guide or another person to tell me what is around… It is independence."* *"I would be able to have equal opportunities and I would have the possibility to visit a museum."* *"I believe that this is what would give us the motivation to go to museums and would provide us with equal opportunities and treatment, such as the ones provided to sighted people."* *"And that there is a sense of equality and also equality before law for those that have a disability and for those who haven't."*
Ethical considerations	*"On the other hand, it would turn people off if they had dead birds on their hands."*
Attitudes of/towards/regarding organisations	*"I understand about research, I understand about cost and things like that, I do think as a visually impaired person we are not catered for, not just in museum, but generally."* *"Totally encourages people to visit a museum, but also to be a part of it... I think if more museums opened up not just by providing audio but by providing tactile, they would give the client, the visitor a better experience."* *"I believe that this is related to each person's interests. I wouldn't go 'mad' about it, but I wouldn't decline such a proposal to visit a museum. I wouldn't be negative towards entering such a museum… It is more attractive to go somewhere and touch something."* *"They (museums) would be a bit more attractive."* *"Of course, I would visit all museums indeed! If I was allowed to touch, I would have visited all museums. At least all the Greek museums."*
Attitudes towards/about other people	*"I think we need our young people to be understanding the world around us."* *"I would also like to see people who have lost their sight as adults not to sit around at home, but to be able actually to do the things they used to do when they had sight and still be able to enjoy them and be able to access and therefore find that love back again."* *"…provide us with equal opportunities and treatment, such as the ones provided to sighted people."*

Table 16: Attitudes related to the experience of the 3D relief and audio application.

Participants' comments refer to their viewpoints regarding the incorporation of similar activities in CH settings. Most of them, even those that prefer other means of interpretative support or those who do not "fancy" museums, recognise the usefulness of replicas and their

value as means to understand exhibits and CH. Many users, implied that CH organisations do not yet provide what is needed for visually impaired people and do not do enough to demonstrate that they recognise them as part of their audiences. Hence, the provision of replicas would make museums more attractive and encourage visually impaired people to visit them (16 responded that they would go to museums more often; whereas 5 stated that they would go anyway but museums would become more attractive). Moreover, some users noted the difference replicas would make to help other groups of people with impaired sight to continue their life and understand the world better.

By looking at the data, it becomes clear that a significant topic about self-esteem, freedom, accessibility and equality emerges (attitudes towards people/organisations relate to this too). As such, the words *freedom*, *equality* and *independence* appear in data as consequences of engaging with the relief. Therefore, it could be argued that similar experiences (e.g. with smart replicas), have the potential to support basic human rights by allowing people to feel independent and responsible for themselves while enjoying equal access to cultural heritage resources; something explicitly mentioned in the Article 30 of the UN *Convention on the Rights of Persons with Disabilities* (2006) as part of the fundamental rights and freedoms of persons with disabilities (see also (Disability Discrimination Act, 1995; Equality Act, 2010).

Lastly, a topic highlighted by one participant is related to ethical considerations that might arise if handling a stuffed bird (i.e. the real exhibit) which is an issue that digitally fabricated artefacts might be able to address up to a certain point.

5.5.4.4 Skills

The whole experience of exploring the relief with the complementary support of the audio application challenged people to use their listening, thinking and tactile skills. The process also involved visual identification for those who had some level of sight.

The observational notes suggest that most participants were skilled in combining their senses and were able to identify all or most of the elements on the relief. Only one participant could not follow any of the description and relief exploration. In most cases, users followed meticulously the description and some even took advantage of pauses and other intervals (e.g. the kittiwake's call) to further explore the shapes of the relief. Six participants were particularly fast in exploration and moved very quickly to the next element or seemed to find the pauses in the audio description tedious (one mentioned that pauses could be shorter).

Amongst them, four (4) were congenitally blind and aged between 25-39 years old. Two (2) were blind with some visual memory; one aged between 25-39 years old and the other 50-59. Such data might demonstrate the relevance between the type of impairment (all were blind), tactile training possibly from a young age (they were all members of CERB) and younger age that might bring confidence with technology facilitated explorations.

On the other hand, few older participants found it difficult to synchronise themselves with sound and touch. These users occasionally identified elements, while other times seemed lost. Nonetheless -apart from one participant who completely ignored the relief as she had enough vision left- all kept coming back to it in an attempt to "exercise" their senses, especially touch, and "decode the object" that was in front of them. One last remark with respect to skills concerns one participant who, even though possessed some vision, kept closing his eyes while navigating on the relief. It seemed that he wanted to isolate his listening and tactile skills from the interference of sight. Later, during the interview, he referred to blindness awareness.

Participants regularly mentioned or implied the idea of skills during the interviews and open-ended questionnaire questions. During the interviews, they were questioned about the general impression of the experience and whether they would talk to others about it (intellectual and communication skills). Based on their responses a set of subthemes emerged under the main theme of skills. These are presented in table 17.

Theme: Skills	
Subthemes	**Quotes**
Tactile skills	*"This is a new venture. Feeling is a different finding."* *"I started trying to see through the haptic exploration of the relief."*
Communication skills	*"No, I don't think I could explain it properly, I'm sorry."* *"No, probably not (talk to others about it)."* *"I should certainly describe to my wife what it is, yes."* *"Of course. Like I talked to you about my experience with the 3D printers. This is a step forward (the relief). This is the important thing."* *"Yes, and I would also give it to those doing research about these things. I would tell them about it. I really mean it."* *"Yes happily (talk to others about it). I mean I do talks for Worthing, for Sight Support Worthing, I speak on behalf of guide dogs. I mean if I ever did, I would be very happy to, because we've had quite a lot of experience."*
Combination of skills	*"'It is difficult to get it and have to keep moving while the description lasts."*

Theme: Skills	
Subthemes	**Quotes**
	"If you are concentrating on something here with your hands, your mind is concentrating on that and not on the audio." *"You placed things correctly and I think that it is quite interesting using your kinaesthetic and your…"* *"…actually, what happened is you are using three senses in a sense, because you are using your listening skills, your feeling skills and your vision."* *"Yes. It was the combination of these elements, the audio and the relief."*
Connecting to other people's skills	*"This is the best tactile I have ever worked with. It is simplistic and it would be particularly useful for blind children."* *"Because many congenitally blind -I am not congenitally blind, I got 'transferred' at the age of 15- have a very odd perception about birds. Completely. And when they touch a bird, a complete reversal of the idea that they had in their minds happen."* *"I thought it was interesting to, to actually feel it and understand how totally blind people can determine what they are like."*

Table 17: Skills related to the experience of the 3D relief and audio application.

Participants' responses corroborate in a way the observational interaction data. Some people found it easier and enjoyed deploying many senses to explore the relief, while others found the combination of skills challenging. For one participant, the tactile exploration was a "new venture" suggesting that he had no previous experience with this kind of reliefs or raised images. As for communicating the experience, twenty-two (22) participants stated that they would mention it to others and felt confident in explaining what had happened, whereas two (2) did not feel capable or wanted to talk about it. One participant did not respond. Lastly, it was particularly interesting to discover that some participants associated the act of exploring the relief with other people's skills. Two blind participants, who were working in teaching facilities with visually impaired children, critically thinking about the experience suggested that the relief would be useful for young people. Finally, a partially sighted user felt connected to blind people in a sense of understanding their skills.

5.5.4.5 Behaviours

The behavioural outcome of the experience highlights people's actions, possible changes in their lives and further progress that might promote skill acquisition and learning. Behavioural data are closely related to skills and engagement/interest (5.5.4.4 and 5.5.4.2) as far as it concerns the immediate interaction with the relief. During the interviews, most of the

behavioural data resulted from questions around the general impression about the experience; possible communication of the experience with other people; and ending participants' comments and thoughts. The main subthemes as emerged from behavioural data are presented in table 18.

Theme: Behaviours	
Subthemes	**Quotes**
Future trialling and further development	*"Whether it is really going to have any potential currently, because things are moving so fast, I have to be honest I don't know… I definitely think it is worth exploring how you can use 3D objects more and how to use, link it to descriptions."* *"I would like to see it really developed. And I would like to see how, you know, in what way could it be developed further..."* *"I would even like to be able to download the map of the museum in order to know how to go, to visit in a comfortable way."* *"The first thing that came to my mind is that you have to continue these efforts, not only you but more people and institutions."* *"I would like to say that this is a good effort and it would be good if it could be expanded beyond the frame of a research... to have it as something standard, as something that we can find and not something distinct or different."*
Change in accessing information and CH organisations	*"I believe it is very important because it helps us to get to know animals or objects that would be very difficult to see in reality."* *"So, to have something tactile would not only improve, but it would make the experience more realistic, backed up with the audio."* *"I think that the joy would be that there would be even more access and more availability than what we have at the moment."* *"I would also like to see people who have lost their sight as adults not to sit around at home, but to be able actually to do the things they used to do when they had sight and still be able to enjoy them and be able to access and therefore find that love back again."* *"So, imagine that I am a blind person in Thessaloniki. And if I wanted to see an artwork in London, this is far away for me. I could have seen some artwork in this way."* *"If I was allowed to touch, I would have visited all museums. At least all the Greek museums."*
Change in professional practices	*"Very good. I would save me having to take things out of the stores (for handling sessions) … obviously they (curators) could actually look after the objects in the stores, so they would actually last longer."*
Participation	*"Totally encourages people to visit a museum, but also to be part of it."*
Learning desire or progression	*"Yes, well I'm always trying to learn something new."*

Theme: Behaviours	
Subthemes	**Quotes**
	"I am fascinated by the 3D printer… For me, I'd like to get my hands on it…" *"And this would motivate me to see more exhibits, to go further and generally to become involved in this field."*
Action as result of the experience	*"My daughter is bringing her grandson just for a week from Worthing and - he is 15- I will definitely recommend that she brings him here. I think it would be interesting."* *"I would go with my blind friends to the museum instead of organising just sport events or other events which are considered more accessible."*

Table 18: Behaviours related to the experience of the 3D relief and audio application.

The analysis of the responses emphasises the importance of trialling and development of the idea of using replicas to assist visually impaired users to access information. Even though there is some scepticism, the majority of comments illustrates that the visual impaired community would welcome replicas and relevant applications. Comments further reflect the desire to have interpretative means, such as replicas, as standard available resources in institutions. 3D data could also become available online to download and print before museum visits or when physical access is difficult. This constitutes a possibility that arises due to the technological aspect of replication through 3D imaging and digital fabrication and it would not be possible if "conventional" replication methods were used.

In addition, the provision of replicas would allow visually impaired users to: access information in innovative ways; become interested in CH; visit museums; and have a more "realistic" experience of CH. Some participants also expressed a desire for learning which could be connected to future choices and actions, while two participants mentioned that the experience could result in changes of other people's actions. One user, who had previous working experience in CH settings, noted that having replicas would change professional practices, as curators would not have to take artefacts out of storage so often for handling.

5.5.4.6 Other themes

A set of important themes that have emerged through the qualitative analysis, provide further insights about the experience of visually impaired people with the relief and audio application. These themes resulted from the RXF-based analysis and deployed methods, but might be more prevalent, generic or abstract. Thus, a conscious decision has been made to further present them separately as they deserve special attention (see also 8.4.1).

One of the most important considerations when designing the experiential framework for visually impaired audiences is the importance of **guidance**. A large part of the guidance related comments was concurrently coded under the themes of *Engagement* and *Audio*. Guidance is understood as one of the most important "ingredients" when experiencing replicas. As already mentioned, the addition of the guidance sheet after the pilot study had immediate impact on the way that people got introduced to trials and interacted with the relief. Detailed guidance also refers to the clearly structured audio description of the application. Many participants discussed about the quality of the audio and how it helped them to understand the contents of the relief. Finally, guidance is related to the "preparation" of people before they go to a CH site as well as while navigating it, even before interacting with a replica.

Some representative quotes with respect to guidance were:

"The audio was very good, and I thought that the audio took me around, took me on the right journey..."

"… the guidance was very organised, with respect to where to start from... very correct information was given about the location of each element."

"The fact it took you through stage by stage, it didn't tell you go and explore, it took you through stage by stage, which I think was better, so the guidance of..."

"… you need to focus on the setup. Absolutely clear instructions.'

"It would make the experience far much better. It is the perception of space. It is very important for us to know before going to the museum… For me, it all starts much earlier... I would like the museum to give it to me (the map) to print it at home and then go to the museum with the professionals…"

"Therefore, these (artefacts) could be scanned and then uploaded on a library and downloaded by people. So ok, I can go to the Parthenon, but in this way, I can do my 'homework' beforehand. And this is something amazing."

Another interesting idea is that of **realism**. Some participants expressed their desire for realistic representations for feathers and plants. Until now digital fabrication does not adequately address the need for realistic organic/natural-like material representations. Further research about materials or alternative ways to represent them could provide better

solutions to fulfil users' needs. Realism is also associated with full 3D objects and, as some of the participants mentioned, having a full 3D fabricated object or a real object to touch - whenever that is possible- could be beneficial too. Some relevant quotes were:

"I think you need to be more 3D. That is my instinct."

"The seaweed could have a different texture, a realistic texture."

"My sense is that actually there would be more validity with that (with the use of different organic materials)."

"To me that doesn't do me any sort of thing, it didn't make me excited at all, but if it was a kittiwake and I could have felt it."

Likewise, **"accuracy"**, seems important too. The term is controversial (as explained in 2.5.1), however some users noted that the interpretation of an artefact in the form of a relief is useful to provide an as-close-as-possible representation of the object itself. This representation, though, demands a level of abstraction that is subjectively determined and could definitely be facilitated by researching and proposing advanced, effective, semi-automated or automated methods to extract and represent information from images that would be appropriate for the visually impaired. This is currently an open and rigorous field of research. Some of the users' comments about "accuracy" were:

"And also, I would like to make a remark, because I have seen some more reliefs in the past... that the representation of the third dimension is very good. It has been represented in a clever way, so that it can be understood by someone who has been congenitally blind without visual memory."

"For example, someone can represent, or paint clouds the way they imagine them. Even if this person can see, they might represent clouds the way they want. These things are not always clear or obvious. Whereas this (the relief) gives you the possibility to see it the way it is."

The **portability** of replicas is another factor that seems to play a beneficial role in terms of allowing people to access information regardless of their location (hence related to accessibility as well). Portability further allows to transfer a replica elsewhere. Many of the visually impaired users are able to visit a CH setting only within a preorganised activity. Therefore, having the possibility to access a portable replica wherever they are, somehow

"breaks" the boundaries of institutions and brings heritage close to them. Some data related to portability are:

"Therefore, these (artefacts) could be scanned and then uploaded on a library and downloaded by people. So ok, I can go to the Parthenon, but in this way, I can do my 'homework' beforehand."

"So, imagine that I am a blind person in Thessaloniki. And if I wanted to see an artwork in London, this is far away for me. I could have seen some artwork in this way."

"I would even like to be able to download the map of the museum in order to know how to go, to visit in a comfortable way."

One last theme that emerged from this case study was about the **fragile nature** of replicas. In many instances, people were afraid that they could break the replicas, even though they are made of plastic and could be easily replaced. Observational data suggest that, in some instances, the curators behaved as having a really valuable, fragile object in their hands, when handing a replica to the visually impaired people (influencing their behaviour). Such remark might highlight a general perception about the products of digital fabrication, which in some cases seem to inherit the non-touchable features of their original "ancestors". Thus, boundaries might still exist, and people and CH organisations need to cross them when deploying the technology and its products. A characteristic comment from a participant who considered fabrication technology (and its products) to be difficult or hazardous to access is:

"For me, I'd like to get my hands on it (on a 3D printer), but probably this would be a bit dangerous."

5.6 Conclusions

The results of this case study demonstrate how unique an experience with the involvement of a replica can be for each person with sight impairment. Moreover, there is great perceptual variation in learning, engagement, enjoyment, attitudes, skills and personal development, as effects of the experience. The results also highlight the importance of each respondent's personal context, not only in terms of age and impairment but also with respect to different interests, previous experiences with artefacts, as well as familiarity with technology and visits to CH settings. Something that is obvious though and affects the social aspect and the perception of the whole experience, is that blind and partially sighted users have encounters

with CH mostly under “institutionalised occasions”. As stated by many participants, the provision of replicas could promote independence and enhance a sense of equality. It would, hence, boost museum visits and motivate people to get to know their heritage and the heritage of other countries too.

As for the key outcomes of the physical context of the experience -also corroborated by the qualitative data- these testify how crucial guidance is. Thus, guidance is imperative when preparing a visit to a CH setting, when getting there and when introducing novel interpretative means, such the replica and mobile audio application, to the visually impaired users. The significance of guidance and clear structure is moreover necessary for the audio description, which in this case followed guidelines as explained in 5.3.3.2.

Another topic that emerged from the research is related to challenges in evaluating ubiquitous applications within “living experiences” with audiences like the visually impaired. Many users found it difficult to rate the ease of use of the application. In addition, it was implied by some users that the examination of usability through task measurements would not be the most appropriate one for CH interpretative applications (see 3.4.4 and 4.4.2). In any case, applications that involve replicas and other media with the use of devices need to incorporate functionalities (e.g. third-party software) to facilitate navigation of content and device control by the visually impaired.

As far as it concerns the properties of the relief itself and people’s impression about them, all were mostly positively rated by both groups without great variations between partially sighted and blind users. The relief seems to be a welcome addition to the interpretative equipment of museums to represent dioramas. There is certainly room for improvement, especially for textures (natural-like and organic) colours and the ways that “peculiar” objects such as the whelk eggs are represented. These could be presented in alternative ways without sacrificing the “faithfulness” to the original object; maybe by expanding the audio description to include more details about them. Generally, the improvement comments came both from people who positively rated the properties of the relief and those who did not. However, all the participants of this case study who had a connection to CH (working in arts and education), proposed improvements, demonstrating somehow that they could constitute a more “demanding” audience. At the same time, most improvement suggestions came from older participants aged between 50-59 or 60+. Something that could be related to difficulties

when coming across new interpretative means in conjunction with “higher demands” because of their wealth of tactile experiences.

Finally, the qualitative analysis reveals the potential of physical replicas and complementary digital applications as “vehicles” in multisensorial experiences to: enhance knowledge, through deepening understanding and facilitating learning; reinforce engagement and enjoyment of CH by triggering imagination, surprise and reminiscence; enable visitors to expand their skills while engaging in explorations; change attitudes by accessing information that was not available to visually impaired users before and hence democratise CH, promote self-independence and equality; lead to behavioural changes that would certainly become more obvious if replicas were a standard part of CH experiences for people with sight impairment. Such physical-digital “dialogues”, would place visitor's experience as the main and normative point of interest, while complying with the post-digital character of museums (Parry, 2013).

5.7 Summary

This chapter presented the first case study of the research, detailed its plan and design along with information about the evaluation process that was deployed, and its findings. The RXF framework (Chapter 4) was used to guide the collection of data and provided a structure to analyse the results. First, data related to the personal context were presented, including demographical information as well as visitors’ interests and backgrounds. Then, the social context was described and interactions between people and generally the social aspect of the visit were discussed. The last contextual parameter was the physical context of the experience. Here, the media people paid attention to, the usability aspect of the application, the quality of the audio and the evaluation through subjective sensorial satisfaction rating was presented through quantitative analysis. The results demonstrate how unique an experience can be for each one of the participants and the importance of individual parameters (e.g. interests, age, type of disability). The overall rating of replicas as interpretative means for the examined diorama were positive with room for improvement in future developments.

The last section was dedicated to the analysis of qualitative data, under the experiential framework with respect to awareness/knowledge, engagement/interest, attitudes, skills and behaviours. These themes and their subthemes, as emerged from the participants’

comments, provide evidence on how replicas work within CH experiences. The classification of data suggests that there is great variation on how people learn, engage, enjoy and evolve through the experience with the use of a replica. Some people were more sceptical when expressing their thoughts about it. Nevertheless, the majority of users were positive, and their opinions indicate that there is great potential in designing satisfactory experiences for visually impaired audiences.

The next chapter is dedicated to the second case study of the research and the examination of its findings.

6 Chapter 6: Case study 2 – Picasso pot replica

6.1 Introduction

This chapter presents the second case study of the research, which targeted adult random visitors of the BMAG interacting with a replica that is an "authentic" reproduction of a pot made by Pablo Picasso. The chapter presents the initial inspiration and concept of the case study, it then details all its elements, starting from the museum's collection, the artefact, the target audience, the development of the replica and complementary media and discusses about technology and resources. It then carries on with the evaluation process and discusses about data collection, the pilot study and the amendments that took place before continuing with the bulk collection of data. Finally, the chapter presents the analysis and findings of the case study by following the theoretical proposition of the RXF (Chapter 4).

6.2 Planning the study

This case study investigates how another target audience responds to the existence of a replica within an experiential framework. At the planning stage and through collaboration with various stakeholders the contextual parameters or "ingredients" of the case study were considered; hence the artefact to replicate, the collection and gallery it is exhibited in, the target audience, interpretative media, as well as the purpose of the replica and other details related to the feasibility of the plan (in accordance with the RXF, see 8.4.2.1).

In this case study, useful input derived from the literature review as presented in Chapter 2 and particularly examples of audience engagement by using digitally fabricated artefacts in multisensorial experiences. Also, participation in events where digitally fabricated replicas were deployed to enhance CH interpretation provided input, as well as the collaboration with the curator of Decorative Art from the BMAG. Museum walks or field walks (Avram and Maye, 2016) have proved to be valuable methodological tools to employ when designing an exhibit or activity in this case too. Hence, when discussing about deploying an artefact from the Decorative Art collection for the research, while walking around the museum, the curator suggested some of the exhibition "highlights". These are usually objects with an interesting appearance, form or story around them. Such objects usually intrigue people and are often used by curators as "engagement vehicles" when organising a talk or a workshop at the museum (Royal Pavilion & Museums, n.d.). After this museum walk, a list of objects that could

be good candidates -both for the curators' requirements and the research- was produced. This list was then further discussed and examined with respect to feasibility as for the digital imaging processes and fabrication and the bird pot was chosen for the case study.

The bird pot (*Pot Oiseau* by Pablo Picasso) constitutes one of the key artefacts of the collection that are exhibited in the "flagship" central gallery of the BMAG (Royal Pavilion & Museums, n.d.); could be used in workshops and future outreach events as suggested by the curators; has mostly a matte finish that allows acquisition by a structured light scanner; and has a rather unusual shape that would demand some experimentation during the fabrication phase. Moreover, this particular artefact could trigger interesting discussions about authenticity, as the object in the glass display of the museum is an "authentic replica" of a Picasso's ceramic, made by the workshop that he personally licensed to replicate his designs. Therefore, it was decided to proceed with this artefact. The objective would be to support visitor interpretation of one of the "key artefacts" of the gallery through the deployment of the replica and complement the overall exploration with audio-visual content (this would be agreed with the curator).

6.3 The development and design of the study

This section details the main elements of the experiential framework of the case study. Thus, it provides information about the contextual parameters or "ingredients" of the study, i.e. the collection and the chosen artefact, Picasso's work with ceramics (in order to understand the nature of the object and complementary media), the chosen target audience and the design and development of the replica and complementary media, along with information on the technology and resources (see 8.4.2.1 on how to deploy the RXF to facilitate the design of a replica experiential framework).

6.3.1 The collection and Pot Oiseau

The Decorative Art collection of the BMAG has been designated of National Importance by the Arts Council. The collection includes artefacts that date from 1750 to present. Two of the museum's galleries are dedicated to the exhibition of this collection by showcasing furniture, glass objects, ceramics, metalwork, textiles and other artwork. Part of this collection is Pot Oiseau (bird pot), which is exhibited in the 20th Century Art and Design gallery, which is the main "flagship" gallery of the museum (Royal Pavilion & Museums, n.d.) (fig. 45). The pot was

donated to the museum in 2012 by the art collectors and philanthropists Jean and Eric Cass through the *Contemporary Art Society*.

Figure 45: The BMAG (left) and the 20th Century Art and Design gallery (right) (Royal Pavilion & Museums, n.d. and Wikimedia under Creative Commons).

6.3.2 Picasso as a ceramicist and Pot Oiseau

Picasso is mostly known for his work in painting and sculpture. However, pottery is what he dedicated himself to in the last decades of his life, when having an already matured artistic expression. Pablo Picasso (1881-1973) became fascinated with ceramics after visiting the Suzanne and George Ramié's Madoura workshop in Vallauris, a coastal area in Southern France between Antibes and Cannes. Picasso got impressed by the scenery at the workshop and the skills of its potters. He recognised the opportunity to engage into a new artistic exploration. After his first visit in summer 1946, he moved to the area in 1948 and stayed there till 1955. The artist spent time at the Madoura workshop on a daily basis and, after moving to Cannes in 1955, kept receiving ceramics to decorate at his new workshop. The pieces would then return to Madoura to be fired. Picasso produced more than 3500 ceramic designs over his lifetime (de Waal, 2003, p. 133).

Picasso, not a potter himself, quickly reconfigured traditional working methods. Hence, he either decorated, modelled and manipulated forms that the master potters produced for him (based on his guidance) or used the standard shapes that were produced at Madoura. The artist learned all the methods to paint and fire clay and even invented his own methods to decorate ceramics. Apart from decorating, manipulating and altering pots were also parts of

his artistic expression (Arts Council and Tate Gallery, 1967, pp. 16–17; New Walk Museum & Art Gallery, 2007, p. 14; Tacoma Art Museum, 1998, p. 66).

The fact that pottery naturally includes the process of replication was also acknowledged by Picasso, who wanted his ceramics to be accessible to everybody. With this stance in mind, he agreed to allow the workshop to market his ceramics and asked that there would always be something available for everyone to buy. In order to produce replicas of Picasso's work, the Madoura craftsmen were trained to use the artist's techniques. Picasso was so impressed by the quality of work, that he kept authorising Madoura to produce and sell *editions* of his original designs till the end of his life (New Walk Museum & Art Gallery, 2007, pp. 16–21). Except for creating *editions*, the artist explored further the replication processes and launched more copies of his designs known as *empreintes originales* (original imprints). In this case, the copying process resembles printmaking. A plaster mould would be decorated and carved by Picasso before getting completely hard. Then, a sheet of clay would be pressed on the mould to get the reverse design. To replicate large pots, the artist would shape and decorate a pot by adding clay and carving its surface. Then a plaster mould would be made from the pot and more *empreintes* could be produced. Picasso also created variations of his *empreintes* and extended the idea by deploying another artist to produce editions in silver and gold (New Walk Museum & Art Gallery, 2007, pp. 27–30).

The artistic style of Picasso's ceramics clearly reflects his revolutionary work in cubism and often presents surrealism influences too. Place, history and tradition play an important role in his creative expression. Hence, there are clear associations between Picasso's pottery and ancient Mediterranean subjects, as they emerge by the history of Antibes, the ancient Greek colony of *Antipolis* (which is very close to Vallauris). Ancient gods, mythological creatures and animals with peculiar shapes appear on his works. These creatures never exactly correspond to classical prototypes and are rather uniquely interpreted by the artist's creativity (New Walk Museum & Art Gallery, 2007, pp. 33–38; de Waal, 2003, p. 136).

With ceramics, Picasso re-examined the relationship between forms and space and "broke" the boundaries between painting and sculpture. By experimenting with a variety of themes, materials, techniques and media, he expanded his vocabulary demonstrating his remarkable creativity, expressive possibilities, artistic diversity and playfulness in the last twenty-five years of his life. In addition, his work brought a fresh spirit into the work of potters in the

1950s. His bold shapes, figures and techniques reclaimed the European character and tradition in pottery which had long been neglected due to the perfectionism and influence of Oriental ceramics (Arts Council and Tate Gallery, 1967, pp. 8–13; New Walk Museum & Art Gallery, 2007, p. 11; de Waal, 2003, pp. 136, 145–146).

Figure 46: Pot Oiseau (left) and stamp of the Edition from the Madoura workshop on the bottom of the pot (right).

Picasso's playful attitude, his influences from traditional pottery and creative spirit are all evident in the case of Pot Oiseau. Here, the artist takes advantage of the whole shape of the vessel to create his creature (fig. 46 left). The body of the pot represents the body of the bird. The front spout becomes its head, whereas the sides of the body are decorated with engravings and designs made by brief brushstrokes to resemble its feathers and wings. The back spout with its blue flowing lines imitates the bird's tail. Picasso takes advantage of the available space to paint his figures but maintains a sense of balance between colours and images. As the porous surface of pottery absorbs colour fast and does not allow alterations in strokes, the hand of the artist must have been fast and sure when decorating the original design. His technique would then be replicated by the craftsmen in Madoura to create several editions of this pot. As shown in fig. 46 (right) this particular edition is number 134 of a series of 300 pots that were produced based on Picasso's original design.

6.3.3 Target audience

The target audience for this study consisted of random adult visitors of the BMAG. The participants could either be people without previous experience in the arts and heritage sector or people with some kind of connection to CH (e.g. working in the GLAM sector). As explained in section 3.4.9, data collection included information about past experience and specialist knowledge, in order to see whether there are any tendencies with respect to

people's requirements from replicas when they have a closer relation to CH. As mentioned before, the BMAG is mostly visited by adult people who belong to the age group of 45-54 followed by the groups of 25-34, 35-55 and 55-64 (Thomas et al., 2016). Furthermore, the organisation recognises that technology offers a wide range of opportunities to engage audiences and enhance visitor satisfaction by enriching the interpretative means for its exhibits (Royal Pavilion & Museums, 2016a, 2018).

6.3.4 Development of replica and complementing digital media

6.3.4.1 Design and production of 3D printed pot

The methods that are usually deployed to acquire the shape and appearance of a portable artefact include photogrammetry, 3D scanners and depth-sensing devices. In this case, the shape of the pot was acquired by using the *AICON Breuckmann 3D SmartScan* structure light scanner that belongs to the Digitisation Lab of the UoB. The artefact was scanned on a day that the museum was closed so that curators could take it out of the display. Scanning took place inside a black gazebo that was set up in the Museum Lab (a space dedicated to research). The use of the gazebo ensures that light cannot enter the scanning area, optimizing scanning conditions and results. The appearance (texture information) of the artefact was captured with a Nikon D3500 Digital SLR camera and an 18-55mm Lens in a pop-up light tent that was placed in a storage room beside the Museum Lab. The photo shooting setup (with another artefact from the museum's collections) is shown in fig. 47.

Figure 47: Photographing artefacts (texture acquisition) at the BMAG.

The pot's data were processed in the SmartScan Optocat, MeshMixer and MeshLab editing software with support from colleagues at the Digitisation Lab, in order to duplicate the external shell of the pot and reverse its faces to create the resulting watertight 3D model as shown in fig. 48 (see also 1.8 for the received support). After consultation with the technicians at the 3D printers' lab of the UoB, it was decided to cut the 3D model into three pieces in order to fit the deposition bed of the printer as the purpose was to produce the best possible replica and keep the 1:1 size. Subsequently, all pieces were printed in white PLA (Polylactic Acid) filament on an FDM (Fused Deposition Modelling) Fusion3 F400 3D printer. The pieces were afterwards pasted together, and post-processing steps took place in order to create a pot that would look and feel as close as possible to the original.

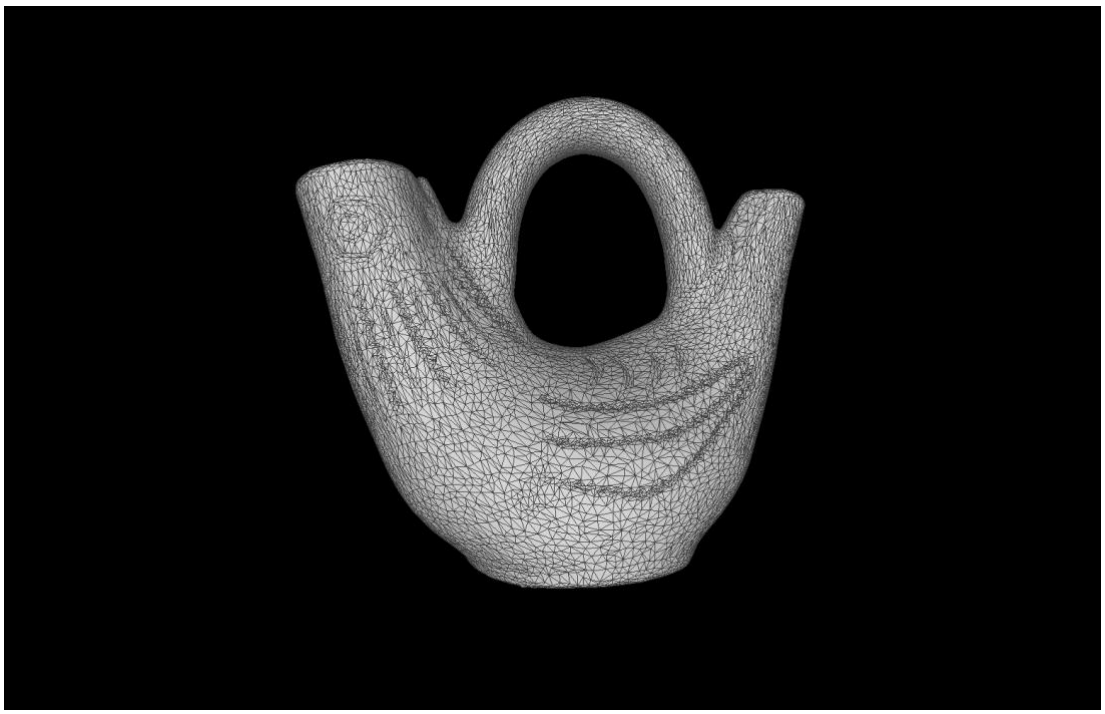


Figure 48: 3D model of the Pot Oiseau.

Some of the key design requirements that were taken into consideration were:

- Shape: The shape had to be kept as close as possible to the original, hence the three prints were carefully pasted together, and small amounts of plaster were added on the parts where the prints joined to hide the attachment lines. Some plaster was also added inside the pot to fill in small gaps around the rim. Excessive plaster was sanded after drying.
- Texture: In order to acquire a texture that would feel close to ceramics, the pot was covered with several layers of a mixture comprising PVA (Polyvinyl acetate) glue,

marble powder, white acrylic colour and water. The pot was afterwards lightly sanded to acquire an even texture. The pot was finally given to the artist Russell Webb, from the Conservation department of the RPM, in order to work on its decorative aspect. The artist added depth to areas of scored decoration using wood engraving tools and additional sanding.

- Colour: The artist painted the replica to match the unglazed areas of the original pot and also darkened some of the scored areas to create an illusion of depth. Then, he discoloured the handle to replicate some signs of handling that are evident on the original and applied acrylic colours to match the decoration of the pot. In the end, the exterior of the pot was sprayed with matt varnish to recreate the unified finish of the original. The several stages of work to replicate the appearance of the pot are depicted in fig. 49.

Figure 49: Working on the decoration of the replica. Photos courtesy of Russell Webb.

- Gloss: Several coats of Golden GAC-200 acrylic glaze were applied in the interior of the replica and around its rim to replicate the appearance of vitreous glaze as it appears on the inside of the original pot.

- Weight: The weight of the replica that was printed in PLA was very light and very far from the weight of the original pot (which weighs 1418gr). Thus, it was decided to pour liquid plaster (plaster of Paris) into the pot to add weight and then left to dry. The final weight or the replica was 1082gr and felt close to the original.

6.3.4.2 Development of video

A video to complement the exhibit and its replica was also produced to provide extra interpretative information and support the visiting experience (fig. 50). The video was produced in Apple's video editing software iMovie 10.1.12 by the author of this thesis and then an application was developed by colleagues at the Digitisation Lab in CEM using the Android Operating System (OS) by deploying the Android Software Development Kit (SDK) in order to loop the video on a Samsung Galaxy Tab S3 (2017), 9.7" Tablet, 32 GB, Wi-Fi (see also 1.8 for the received support).

Figure 50: Screenshots from the video. Textual information and images (image of Picasso from Wikimedia, under Creative Commons) along with video fragment from 1954 documentary 'Incontrare Picasso' by Luciano Emmer.

Videos are considered valuable additions to exhibitions as they present audiovisual narratives which are interesting and dynamic, while conveying information about processes and complex stories around an artefact or theme. The video was decided to be short as this could result in stronger holding power with respect to visitors' attention (Serrell, 2010). Its final duration, after a number of revisions in collaboration with the Decorative Art curator, was two minutes and twelve seconds (2:12).

The video was developed around four sections with some textual information and visual material about: Picasso's move to Vallauris and South France; his work with pottery; the licensed editions and original imprints produced along with Picasso's methods for replication; and Pot Oiseau. Fragments from the 1954 documentary *Incontrare Picasso* by Luciano Emmer, featuring Picasso forming a similar bird pot, was also included in the video. Music was added to enrich the experience too. The chosen piece was *Danza Espanola No. 1* from the opera *La vida breve*, written by Manuel de Falla in the beginning of the 20th century. Picasso himself collaborated with Manuel de Falla in 1917 for the ballet *The Three-Cornered Hat or Le tricorne*. Manuel de Falla had written the music for the ballet, whereas Picasso worked on the set decoration and costumes of the opera (Beechey and Shone, 2006).

6.3.5 Management, resources and technology

All the assets for the case study have been agreed and produced by the researcher and colleagues at the UoB in collaboration with the curators of Decorative Art from the BMAG.

The artefact was scanned by the author of this thesis and processing of the 3D mesh happened with the help of colleagues from the Digitisation Lab of the UoB. Colleagues from the same team developed the Android application for the video about Picasso (produced by the author of this thesis). Technicians at the 3D printing suite of the UoB printed the replica pot and post-processing was done by the researcher. Finally, an artist from the RPM undertook work on the decorative aspect of the pot, in order to make it look as close as possible to the original. Budget from the School of CEM and the CSIUS of the UoB enabled accessing equipment as well as the production of all assets.

As far as it concerns the fabrication technology, it was decided that 3D printing was the most suitable solution for the production of the replica. Such decision was related to the availability of resources at the UoB and the desire to produce an as much as possible "accurate" replica. Moreover, the replica should not be particularly expensive, it should be made from safe materials (that will not harm visitors if the replica brakes) and could be relatively easily replaced in case of damage. Although, a more traditional approach to make a replica pot could have been deployed, this would require freely replicating the pot and hence compromising its "accuracy". A solution would be to work with the original in a more obtrusive and potentially risky way, in order to produce a mould out of it and then generate the pot with a casted material. Such process could become expensive, casted materials could also brake

(potentially harming visitors) and future replication would become dependent on the preservation of the mould. In order to avoid all those risks and secure “accuracy” and replicability, digital fabrication was opted for the production of the replica pot.

6.3.6 Overall study set up, preparations and processes

As stated before, each case study’s development was based on exhibition design principles while deploying the RXF framework to facilitate the design of replicas and their integration in CH experiences (see 8.4.2.1). A summary of the preparations and set-up of the case study is presented below:

- **Ideation and concept development:** Input for this case study derived from discussion with colleagues and researches working in similar fields, museum professionals, CH audiences and literature review in order to develop the initial concept for the case study with random adult visitors of the BMAG.
- **Resources:** The available resources for the case study were also listed to examine the feasibility of plans. Resources included digitisation equipment (3D scanner, turntable, black gazebo, camera, light tent, tripods, lights, light stands); software; technical support (digitisation lab, 3D printing suite); digital fabrication machinery (e.g. available 3D printers and their features); necessary artistic work; tablet and stand; camera and audio recorders for the evaluation sessions; available budget; and access to museum and audiences.
- **Museum/collection/artefact selection:** Through discussions with the RPM officers, the BMAG and its Decorative Art collection were selected for this case study. Museum walks have been useful in this case too, to identify -along with the curator of Decorative Art- the key exhibits or “highlights” of the collection. Further consultation with colleagues at the UoB and consecutive visits to BMAG facilitated the selection of the Pot Oiseau, an “authentic replica” of a Picasso’s ceramic, made during his stay in Vallauris, South France.
- **Audience selection:** Random adult visitors with or without previous experience in the arts and heritage sector were targeted for this case study. Data about the people who visit the BMAG, as well as the RPM’s audience development plans contributed to the selection of such audience group. Access to the target audience was granted by the RPM.

- **Replica development:** Information about the shape of the pot was acquired through 3D scanning, using an *AICON Breuckmann 3D SmartScan* structure light scanner, whereas texture information was acquired via photography (described in 6.3.4.1). Data were processed in suitable 3D graphics software and the pot was 3D printed in three pieces that were later joined together. Post processing and artistic work was also performed in order to produce a 3D replica that would look and feel as close as possible to the original.
- **Media development:** A video was produced in order to complement the interpretation of the exhibit and replica pot. The video included information about Picasso's move to South France; his work with pottery; the editions and original imprints he produced; and Pot Oiseau. The duration and content of the video were revised in collaboration with BMAG's Decorative Art curator. The video looped on a tablet through an application developed using the Android Operating System (OS) by deploying the Android Software Development Kit (SDK).
- **Evaluation:** The methodology and methods for evaluation are described in Chapter 3. Information sheets, consent forms, questionnaires and observation sheets were printed to facilitate data collection. Apart from the printed forms, the equipment/resources used for the evaluation sessions included: the replica pot, the label inviting people to touch the pot, the tablet with the video on loop, camera and audio recorders. Users were observed while freely interacting with the relief and notes were kept in the observation protocol. Once finished, they were informed about the research and asked whether they wanted to contribute to it. When participants agreed and signed consent forms, their observation data were kept, and they were asked to fill in the questionnaire and respond to the interview questions about their experience with the replica. When they did not agree, their observation data were discarded and hence not deployed for the research. The data that were used for the research were later transcribed to facilitate data analysis.
- **Pilot study and data collection:** The pilot study took place at the BMAG with two museum volunteers participating in it. The setup in front of the museum display comprised a table with the replica pot, label, and tablet with stand on. The researcher sat at a distance from the display in order to have visual access to it, without being too intrusive. The pilot revealed that the message on the label to invite people to

touch the replica should me more precise, as well as other details, about the font, music volume and loop functionality of the video. Consecutive data collection sessions took place in the BMAG in the following days and weeks.

- **Data processing and analysis:** Quantitative and qualitative data were transcribed and analysed as described in 3.4.11.

6.4 Evaluation

6.4.1 Data collection methods

The data collection methods that were deployed in this research are described thoroughly in section 3.4.5. Data collection includes both quantitative and qualitative methods that address the research questions in accordance with the RXF as proposed in the theoretical proposition of this thesis (Chapter 4). On the other hand, they allow triangulation of data through the use of different types of evidence which allow a deeper understanding and analysis of phenomena. Data collection methods for the second case study of the research included:

- semi-structured observation notes;
- short questionnaires;
- semi-structured interviews.

A copy of the observation protocol, a sample of a transcribed observation, the questionnaire sheet, the interview sheet along with a sample of a transcribed interview for the second case study can be found in Appendix C.

6.4.2 Pilot study

The pilot case study took place at the BMAG in March 2019. Hence, the setup for presenting the replica and complementary digital media along with the observation spot and interview area were tested (fig. 51).

Two people, volunteering at the museum, participated in the pilot. The curators and the researcher paid attention not to reveal the setup of the exhibit with the replica and video to the volunteers before. The 3D printed replica was placed on a table in front of the display with the original artefact. A tablet with the video playing on loop was also placed on a stand next to the replica and a label with the phrase "*Please touch*" complemented the whole setup.

Figure 51: Setup for the study (left) and observation/interview spot (right).

The participants were invited to the area were the exhibit was and interacted with the replica. The researcher was keeping observation notes while they were exploring the exhibit and interpretative media. When the exploration had finished and after giving informed consent, participants were provided with a single-page, double-sided questionnaire to fill in about the properties of the replica, the quality of the complementary media and other questions related to the contextual parameters of the experience. Each session ended with a short interview that was audio recorded.

6.4.2.1 Lessons learned

The pilot study has proved very useful as it revealed details that should be taken into consideration or altered for future data collection sessions. Some of the topics that came up, resulted from observing the participants and asking them about the experience through the interview process and others were discussed directly with the curator of Decorative Art right after the initial trials. One of the details that were first discussed was about the font size of the textual information both on the video and on the *"Please touch"* label. The curator suggested that it was relatively small and maybe difficult to read. Therefore, both font sizes were increased for better readability in consecutive sessions. Also, one of the participants commented that the volume of the music from the video was relatively loud and distracted

her from reading the information on the screen and posters and from enjoying the experience. Hence, it was decided to keep the volume at a moderate level depending on the level of noise in the gallery in the following days.

With respect to the 3D printed pot and the complementary media, it was decided to place the replica on the table, in a position and direction that imitated the position of the original pot in the display. This aimed to emphasise somehow the connection between the replica and the original. As for the video, it was noticed that the tablet would go into sleep mode after a period of inactivity (when nobody was touching the screen) which resulted in stopping the playback. Hence, an intervention on the code of the application was deemed necessary to keep the tablet and its screen on, playing the video constantly on loop.

Regarding the observation and interviews spot, it was decided to place the chairs and table at a distance that allowed watching people interacting with the exhibit without being too intrusive. Of course, the researcher was not always sitting at the table when observing participants (as this is a dynamic process) and would occasionally stand closer to them. The intention, though, was to maintain a non-obtrusive and an as much as possible discrete presence. Nonetheless, in consecutive data collection sessions, when the area was crowded or when large groups approached the exhibit, it was not always possible to observe what was happening as people would obstruct the way.

Lastly, an issue that was mentioned on the pilot day but became obvious on the first day of data collection was that visitors were reluctant to touch the replica, even though there was the label with the phrase *"Please touch"* on the table. It was surprising to notice that people would occasionally touch the table, the tablet, and the label itself instead of trying to touch the replica. For this reason, the phrase on the label was changed to become more explicit by suggesting *"Please touch the pot".*

6.4.3 Further collection of data

After the pilot study, more data were collected at the BMAG in several sessions that took place between March and April 2019.

6.5 Findings

The following sections describe the analysis of data from thirty-two (32) participants who contributed to the evaluation of the replica and complementing video. The analysis is

structured upon the theoretical proposition as described in the RXF concept (Chapter 4). Hence, it includes information about the personal, social, physical context of the experience along with the analysis of the expression - perception of such experience in terms of the pre-existing themes (awareness/knowledge, engagement/interest and so on) and other that have emerged from data.

6.5.1 Personal context

Thirty-two (32) participants took part in the evaluation. All visitors were observed interacting with the replica and then asked to fill in a questionnaire and respond to some semi-structured interview questions. Eighteen (18) participants were women and fourteen (14) were men (fig. 52). During sessions, there was an effort to balance sampling between men and women participants. However, in many instances, it was noticed that most visitors were women; women were more willing to take part in the research; or men were happy to give their place to a woman from their group. The fact that museums often attract more female visitors has been already corroborated by research (The Audience Agency, 2018). Most of the participants were of white ethnic background (27 out of the 32 participants).

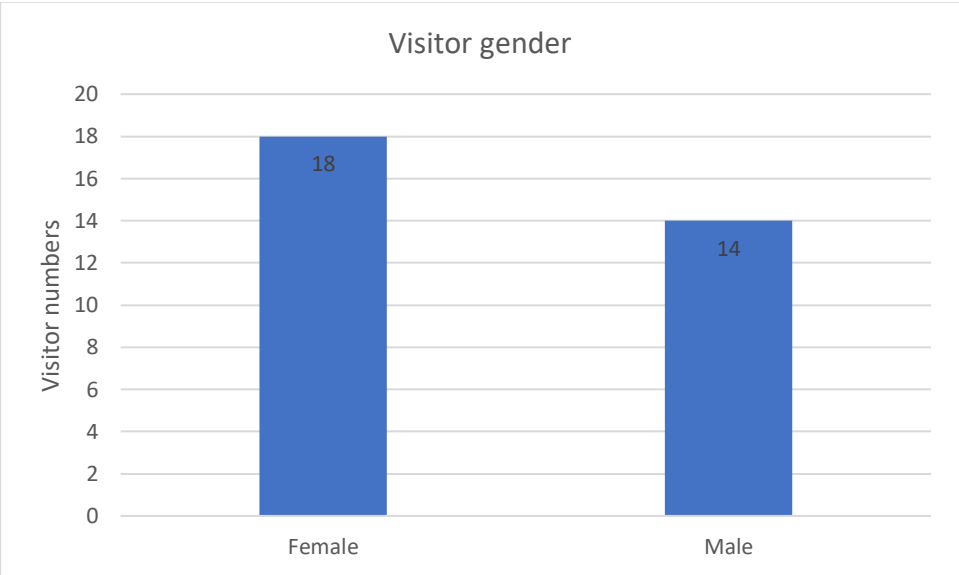


Figure 52: Female and male visitors participating in the case study.

All ages are represented in data. Nonetheless the group of visitors over the age of sixty is overrepresented, as thirteen (13) participants belonged to it (fig. 53). Even though the collection of data took place in morning and afternoon and on different weekdays, it was noticed that the majority of visitors on working days were people of an older age or school children. Again, such remark is not surprising considering trends in population ageing (United

Nations Department of Economic and Social Affairs, 2020) as well as research highlighting that people of a certain age form a significant part of museums' audiences (Matty, 2004; Reeve, 2009; The Audience Agency, 2018).

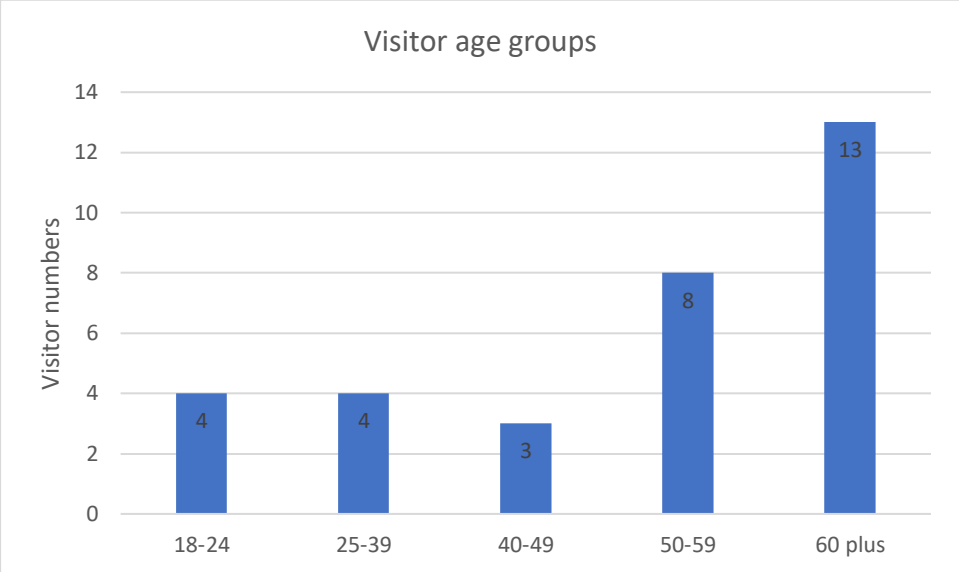


Figure 53: Visitors' age groups.

With respect to visitors' provenance, fifteen (15) came from the local area (less than 10 miles away from the museum) and sixteen (16) from afar (distance between 60 and 6000 miles). As for previous experience from museum visits, the vast majority of participants (31 people) had visited a museum before but their visiting frequency differentiated. Hence, seventeen (17) would visit a museum up to ten times a year, whereas five (5) people would visit a museum more than ten and up to twenty-five times a year. Three (3) people had even more frequent visits, as they would go to a museum more than forty times a year. These were a person volunteering at the museum, another dedicating a lot of time in artistic activities within a museum and a "museum enthusiast" going to museums many times per month. Some visitors did not share information about distance of residence or frequency of visits. When asked about previous visits to the BMAG in specific, seventeen (17) said that they had visited the museum before and fifteen (15) participants stated that this was their first visit there (fig.54). Amongst the latest ones, four (4) lived at a distance between 60-185 miles away from the museum and nine (9) at a distance of more than 200 miles and up to 6000 miles away. Only one lived locally, 2 miles away from the museum, and had never been there before.

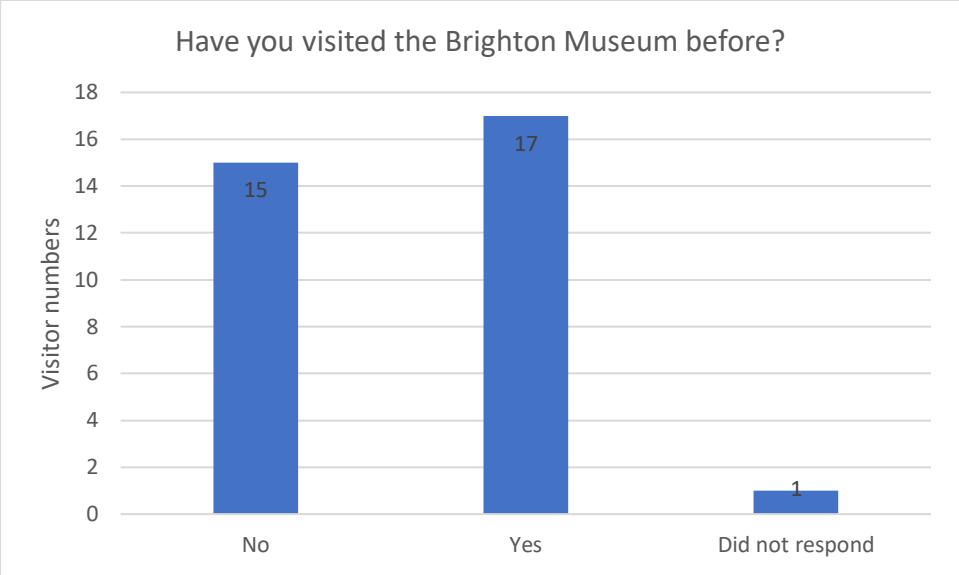


Figure 54: Previous visits to the museum.

More data about visitors' background, and more specifically their occupation, reveal that twelve (12) participants had some connection to CH through their professional or voluntary work and twenty (20) did not. The type of CH related work ranges from museums' and heritage societies' volunteers to anthropologists, artists, teachers and tour guides.

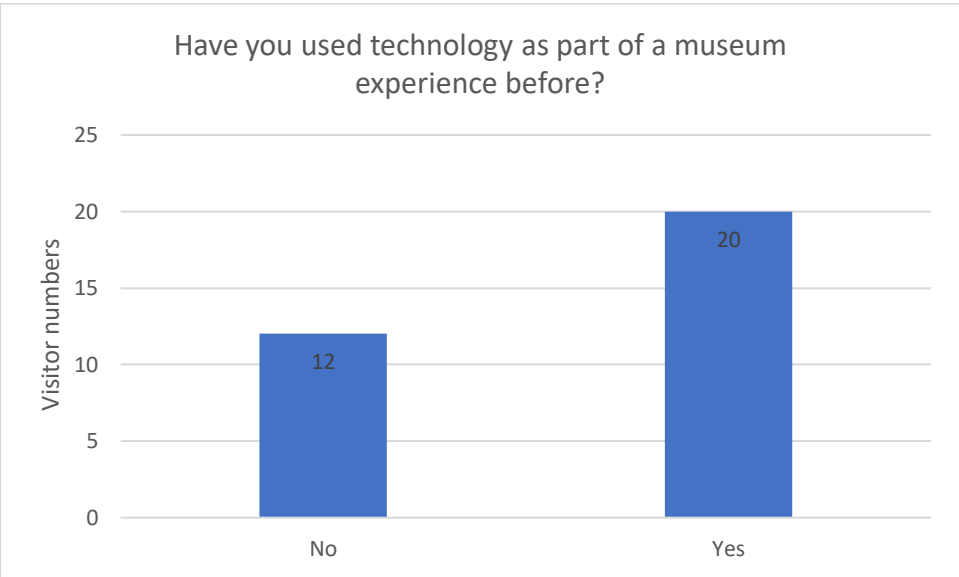


Figure 55: Previous experience in using IT in museums.

When examining people's experience with objects and technology in museum settings, data demonstrate that twenty (20) participants had used technology in museums before and twelve (12) had not (fig. 55). However, most of the second ones (10 people) belonged to ages above fifty and might have not felt confident to use IT in a CH setting. As for touching museum objects, the results are not surprising, as most people had never or rarely touched museum

objects before (fig. 56). Amongst the three (3) that were "always" or "often" touching museum objects, one had previous experience as a museum volunteer and one as an artist.

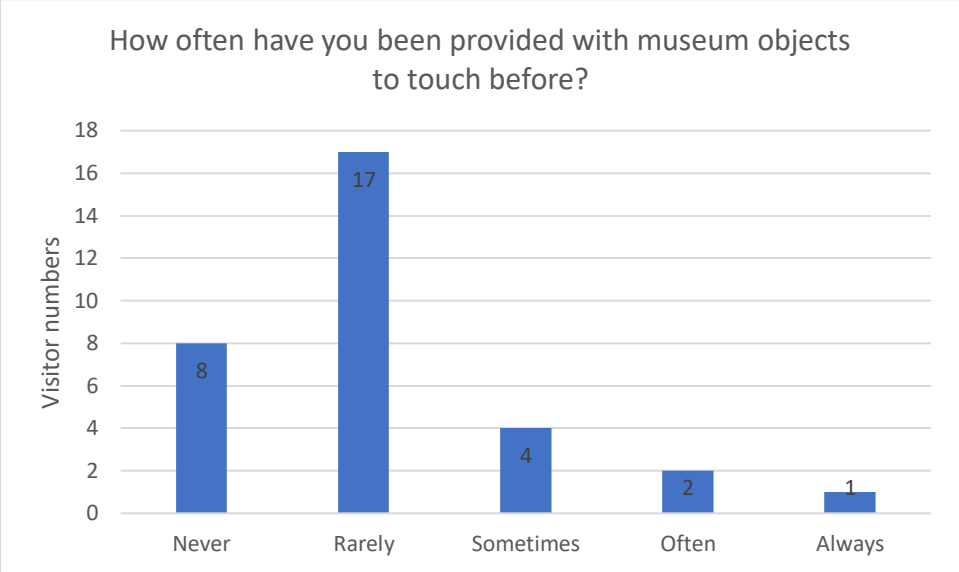


Figure 56: Previous experience in touching museum objects.

With regards to people's expectations, the intention was to find out what people were looking forward to doing during their visit. Table 19 describes expectation tendencies (from strongest to weakest): explore a specific collection; be inspired to make art/work on creative activities; explore collections/general visit; learn and be inspired; nothing in particular; do voluntary work; meet someone; expected to touch artefacts; not expected to be able to touch anything; expected to be asked about the experience. Most people expected to visit a specific collection at the museum, be inspired or work on creative activities and explore the museum in general. Fewer people did not have any particular expectation, while others mentioned that they came to look around and learn, do voluntary work, meet someone or even touch objects at the museum.

Expectations (tendencies)	Participants	Representative people's comments
Explore a specific collection (e.g. Egyptology, local archaeology, paintings) and learn about local history	8	*"Expected to explore the history of Brighton, fishing industry, development of town, art works and ceramic work."* *"I came specifically for the new 'Dig this City' exhibit."*
Be inspired to make art/work on creative activities	6	*"Being inspired for creative work."* *"To see interesting pieces (e.g. field of design) and get an input."*

Expectations (tendencies)	Participants	Representative people's comments
Explore collections/general visit	6	*"Explore the collections."* *"Just to look around."*
Learn and be inspired	3	*"Just take look around and be inspired."* *"Look at stuff and learn stuff."*
Nothing in particular (no expectation)	3	*"Didn't expect anything in particular."* *"Nothing in particular."*
Do voluntary work	2	*"Volunteer work."*
Meet someone	1	*"My friend usually comes for a drawing session and I was going to pop in."*
Expected to touch artefacts	1	*"I thought we might be given the opportunity to touch exhibits from the museum."*
Not expected to be able to touch anything	1	*"Listen, look but not necessarily touch."*
Expected to be asked about the experience	1	*"I expected to be asked difficult questions on a subject I know little about."*

Table 19: Tendencies in participants' expectations.

In terms of people's interests when visiting the museum, as shown in table 20, most participants (13) said that they did not have a specific interest; however this did not prevent them from visiting, as in fact seven amongst them (7) would visit a museum at least four times a year.

Interest	Participants
General collection	7
Specific collections	11
No specific interest	13
Royal Pavilion	1

Table 20: Tendencies in participants' interests.

Moreover, seven visitors (7) were interested in all collections and eleven (11) were interested in specific collections of the museum; with the Archaeological collection/New Archaeology Gallery, the Fine Art collection and the Willett collection of popular pottery mentioned the most amongst participants. One participant mentioned that was interested in the Royal Pavilion in Brighton.

6.5.2 Social context

The social context of the experience is related to the composition of visit, the social environment in the exhibition place as well as the interactions within a group or between groups of visitors. As data show, most people that contributed to the research came to the museum with someone else (20 out of the 32 participants). Research demonstrates that this is not surprising, as almost 80% of museum audiences visit in groups, with the largest part amongst them being adult groups (The Audience Agency, 2018). When it comes to the social environment of the exhibition, it was noticed that the calmer the space was the easier was for people to find the exhibit and dedicate time to it. Therefore, when the area was crowded it was not always easy for people to pay attention to the exhibit and interpretative content.

With regards to interactions between the members of a group, these were mostly of verbal character. The majority of visitors discussed about three topics: a. the resemblance of the replica to the "original", its comparison to it and the way that 3D printing can achieve that (*"…it is so close to the original"*) - something also related to the technological aspect of 3D imaging and fabrication and their success in "faithfully" replicating the artefact; b. the way Picasso worked, his movements while shaping pots as demonstrated in the video *("…the technique is amazing!"*); c. the surprise that visitors felt due to the possibility to touch. Hence, many visitors were turning to their friends or family when reading the label with the phrase *"Please touch the pot"* and pointed at it. Some of their quotes were: *"Look! It says please touch!", "This is perfect! Can I touch?", "It says please touch!", "I was going to say: Oh God, I am so scared!", "This is your chance once in a lifetime to touch a Picasso!"*. Social interaction quotes evidence, on one hand, the variety of discussions that the presence of a replica as interpretative means can trigger. On the other hand, some quotes along with visitor's interview comments corroborate that people are reluctant to touch and when they are given the opportunity to do so, they become sceptical, surprised or scared. This is further witnessed by a visitor who was expecting the alarm of the museum to be triggered by touching the replica and said: *"I saw that, and I touched it and I was expecting it to go BOOM!".*

Lastly, physical interactions between visitors (or occasionally "socially-sensed" expressions) included people bringing their friends and siblings to the area where the replica was placed to show it to them; nodding to them to look at the replica; knocking at the replica to hear its sound; pretending to pour liquid out of it; using the replica like a seashell horn to whistle; and

even posting photos of the original on social media after inspecting the replica. Such interactions demonstrate the richness of engagements that experiencing the physicality of a replica has the capability to prompt.

6.5.3 Physical context

The evaluation of the physical context of the experience is dedicated to the original artefact, the exhibition setting, location and atmosphere as well as the performance of the replica itself along with the other interpretative means. Information about the original artefact has been presented in section 6.3.1. As for the exhibition place and the artefact's location, it has already been mentioned that Pot Oiseau forms part of the "flagship" gallery of the museum. There, participants were able to find the replica easily, as it was placed in front of the display with the "original", in an area adjacent to the central corridor of the gallery. However, not everybody stopped to pay attention to the setup and exhibit. Some visitors simply might not have wanted to. Another reason could be related to the specific location of the exhibit which is placed at the very end of the main corridor of the gallery, constituting an "exit point" to access facilities such as resting areas and toilets. Therefore, in many instances, visitors would quickly skip the main gallery and Picasso exhibit (some came back to it later) to go directly to such facilities[43]. For this reason, the research presents data from visitors who paid at least some attention to the artefact in the display and/or interpretative information.

As for the atmosphere of the gallery, this is mostly dominated by the design and furniture collections. The Picasso pot is placed in a large glass display at the end of the gallery. This display along with another one on the opposite side somehow mark the gradual transition to other exhibition spaces. The Pot Oiseau display is large and relatively well lit. Large posters with interpretative information and a print with Picasso's name and photo attract visitors' interest to one of the "highlights" of the exhibition. The environment is generally calm in that area, apart from times when schools and large groups are visiting.

[43] This could be related to the "museum fatigue" and "object satiation" phenomena as studied by Melton in the 1930s (described in Falk and Dierking, 2013) by following a similar mechanism. Thus, visitors skip exhibits not because of tiredness in the end of the visit, but at the beginning of a visit immediately after entering the museum to satisfy essential or physiological needs (something mentioned by the museum personnel too).

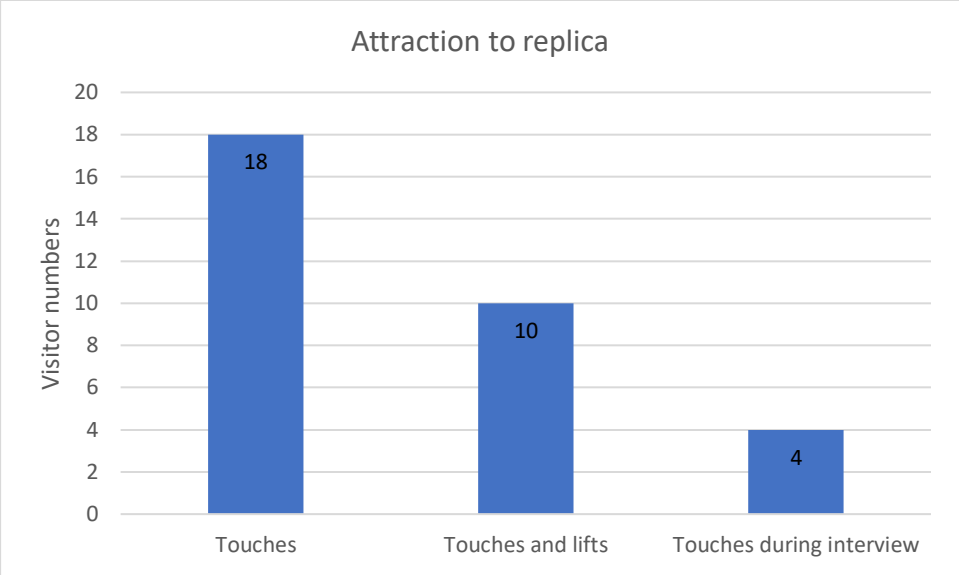


Figure 57: Visitor attraction to replica.

When examining the exhibition setup, visitors were attracted by different aspects of it. Twelve (12) participants explicitly mentioned during the interviews that the replica in front of the display was their first point of attraction. As described by Csikszentmihalyi et al. (1995), for those people the replica might have worked as the "hook" to evoke *situational interest* or *curiosity* in order to gain their attention. The rest of the visitors mentioned the combination of media or prioritised other means (the video or its music, Picasso's photo, printed name on display). Even though all participants manifested some interest for the setup, not everybody touched the replica. Eighteen (18) participants simply touched the replica with their fingers without trying to lift it up or change its position. Ten (10) participants demonstrated a bolder behaviour and lifted the replica, whereas four (4) touched only during the interview (fig. 57). Such findings might suggest that people are still very careful when using a sense (i.e. touch) that they are not used to employ when visiting a museum. Therefore, even when they touch, they limit their physical movements to "modest" levels.

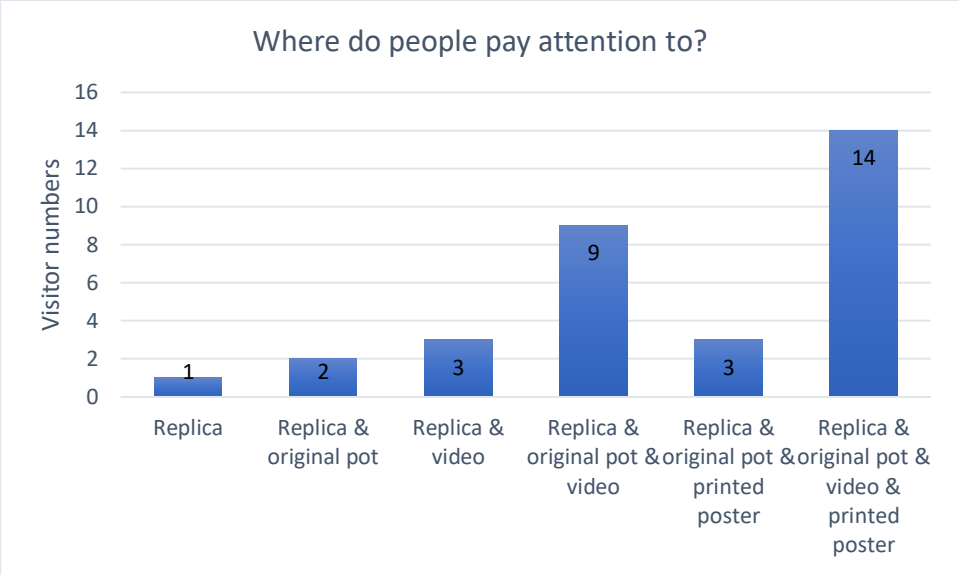


Figure 58: Interpretative media attracting people's attention.

The analysis of the interpretative means visitors paid attention to is presented in fig. 58. Most visitors paid attention to the "original" artefact as well as the interpretative means. Hence, fourteen participants (14) paid attention to all media at a time. Only four (4) participants did not pay attention to the original artefact. Therefore, it might be argued that the presence of the replica in the majority of cases did not distract people from the original artefact; something that CH professionals might fear with the introduction of new media into exhibitions. In addition, the approximate time spent in front of the exhibit and set up with the replica was found to be between 2 and 3 minutes for the majority of visitors (22 out of the 32 participants). Time can vary depending on visitors' interests, background or the social aspect of a visit (to name a few parameters). However, this duration is considerably higher than what other research suggests (Carbon, 2017) about visitors' attraction to exhibits. Also, spending this amount of time seems significant considering that most visitors do not spend more than 20 minutes in an exhibition (Serrell, 1997). Regarding the attraction to the video: most people watched part of it (15 participants); fewer watched it all (8 participants); some did not watch at all (6 participants); two (2) participants watched it more than once; and one (1) watched it during the interview. When questioned about the quality of the video the majority of users (24 out of the 32) were "very satisfied" or "satisfied" with it (fig. 59). One user mentioned that wanted the video to have a slower pace and another that he would prefer the video to play on a larger screen at the eye level.

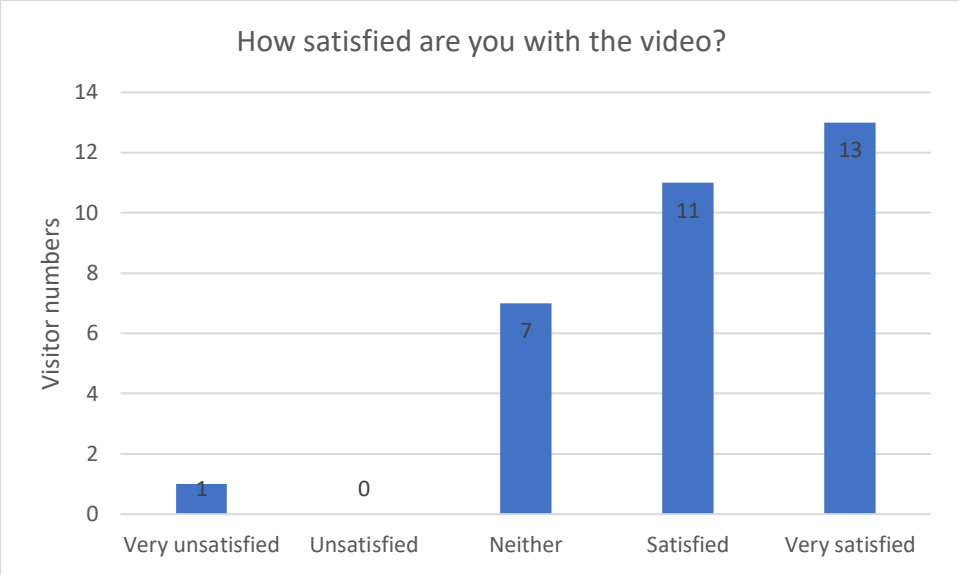


Figure 59: Video evaluation.

When evaluating the replica, people were asked to rate its sensorial properties on a 5-point satisfaction rating scale (see 4.5.3.3). Emphasis was given here to the tactile and visual properties of the replica, due to the nature of the exhibit and target audience. Quantitative data aim at complementing the evaluation of the experience with measurable results about its features. Such effort does not intend to compromise the importance of contextual parameters when investigating social phenomena. The results of this evaluation are presented in the following charts (fig. 60-69).

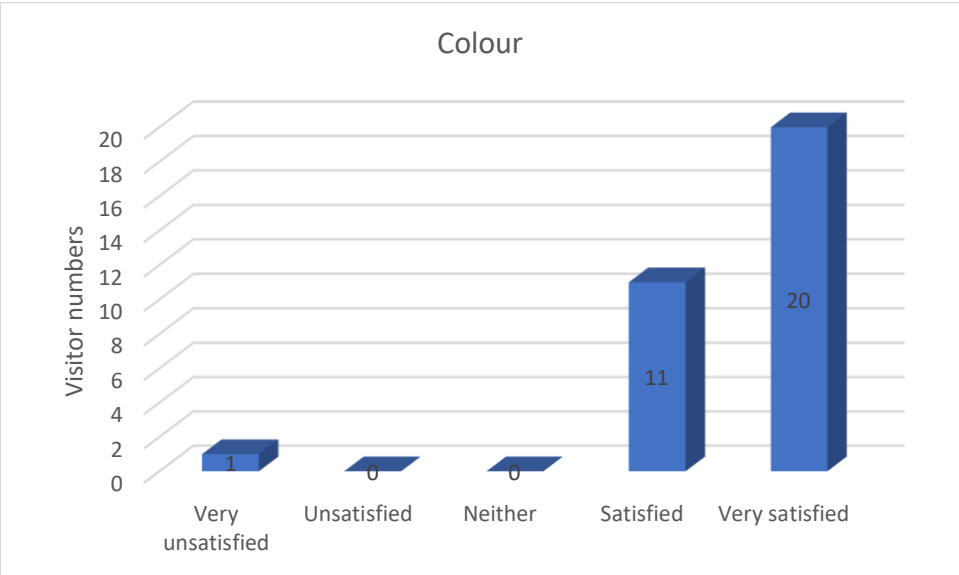


Figure 60: Rating of the subjective sensorial visual property of colour of the replica.

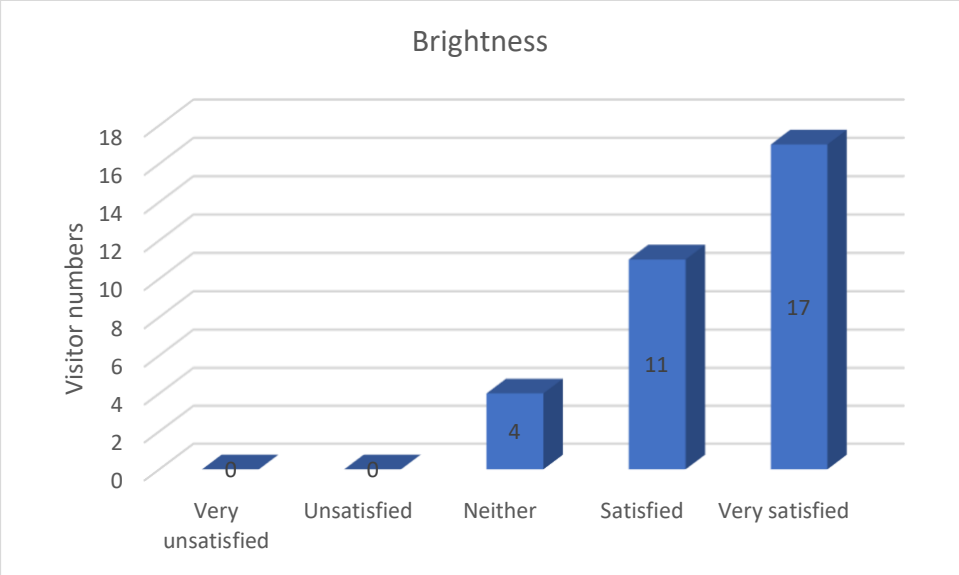


Figure 61: Rating of the subjective sensorial visual property of brightness of the replica.

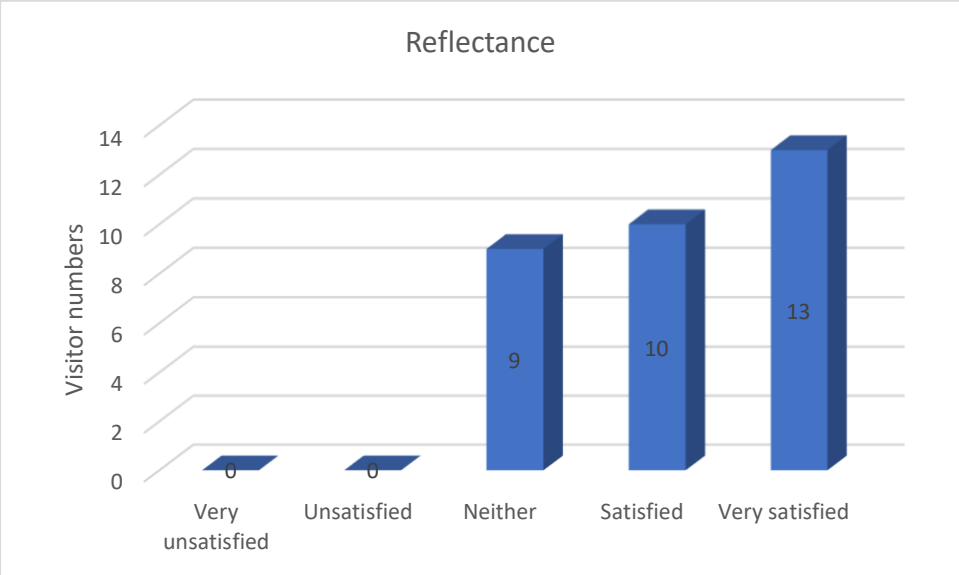


Figure 62: Rating of the subjective sensorial visual property of reflectance of the replica.

Figure 63: Rating of the subjective sensorial visual property of gloss of the replica.

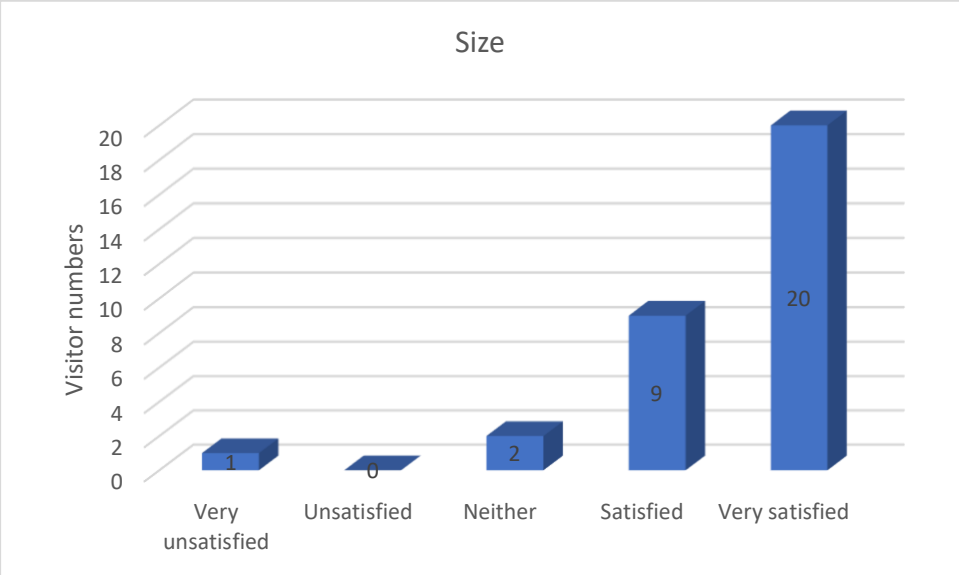


Figure 64: Rating of the subjective sensorial visual/tactile property of size of the replica.

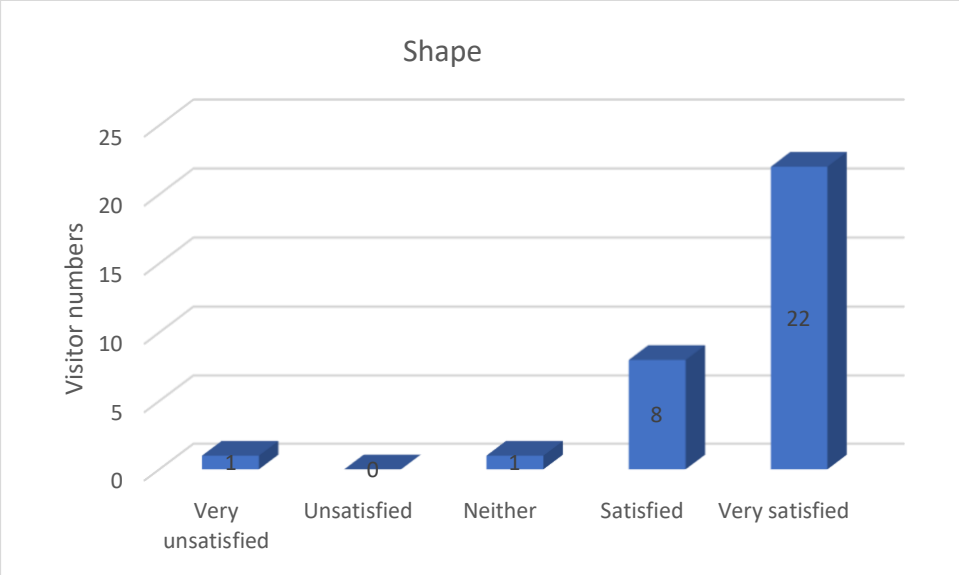


Figure 65: Rating of the subjective sensorial visual/tactile property of shape of the replica.

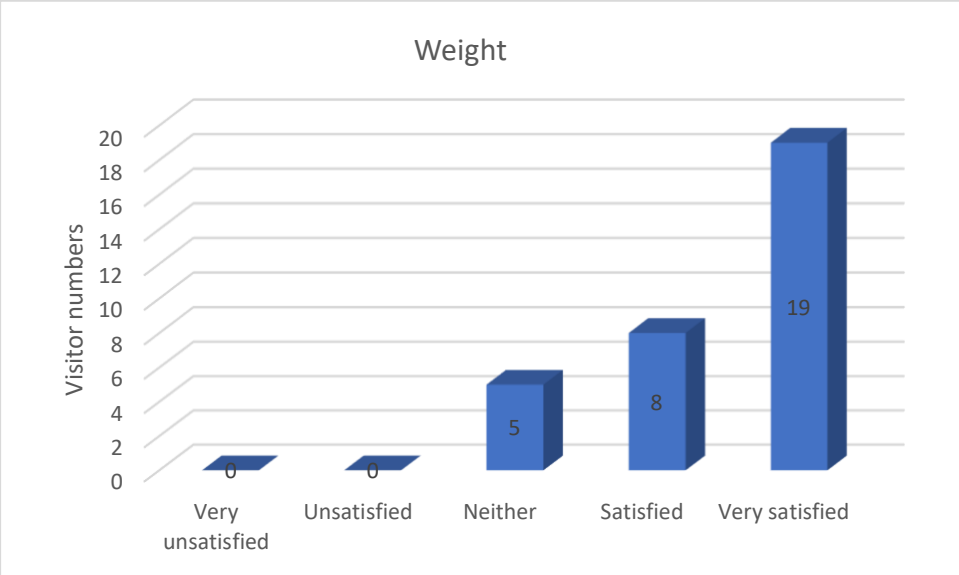


Figure 66: Rating of the subjective sensorial tactile property of weight of the replica.

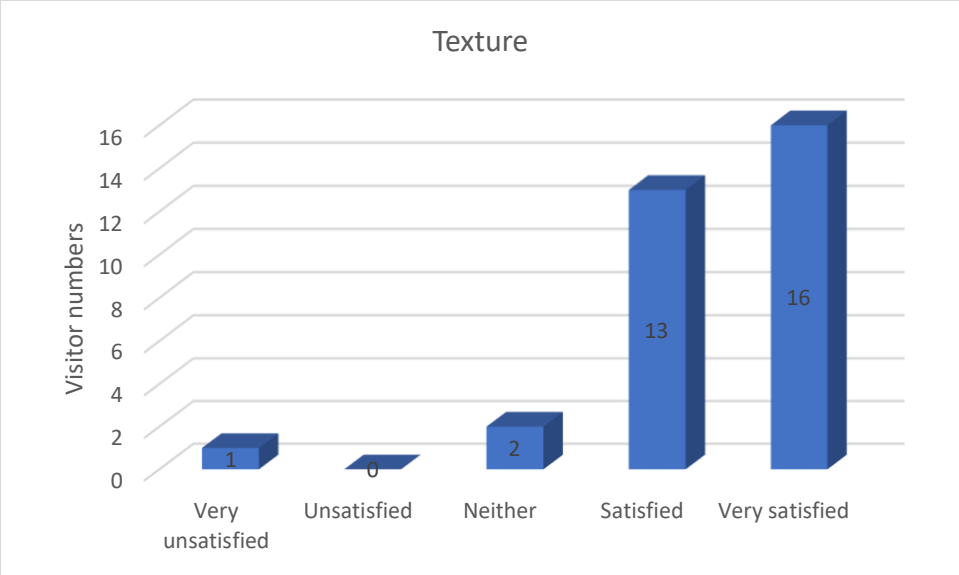


Figure 67: Rating of the subjective sensorial tactile property of texture of the replica.

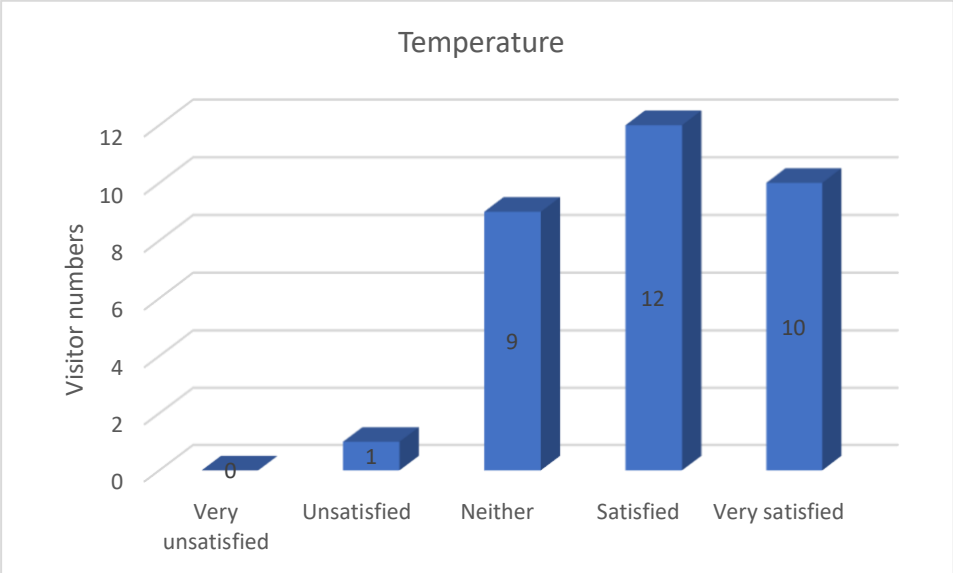


Figure 68: Rating of the subjective sensorial tactile property of temperature of the replica.

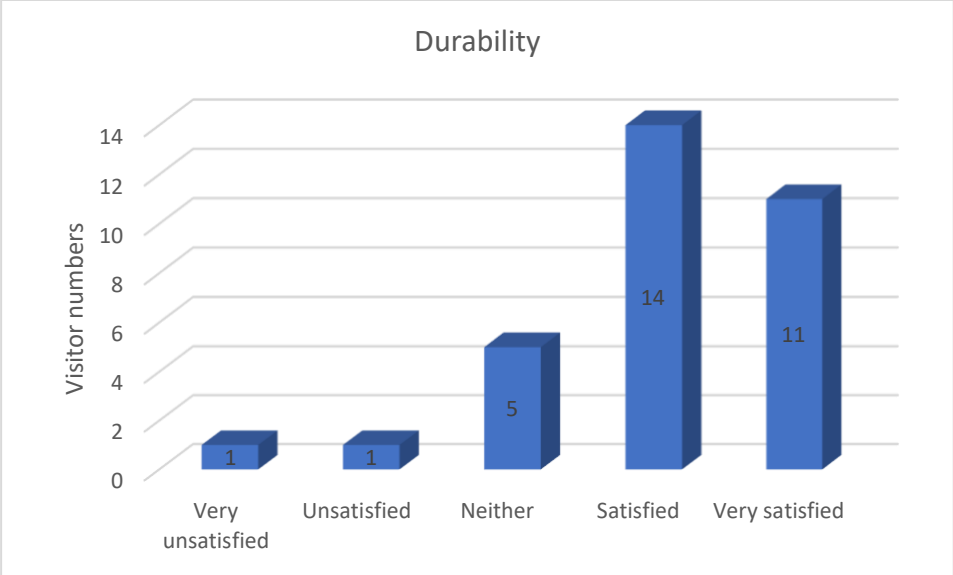


Figure 69: Rating of the subjective sensorial tactile property of durability of the replica.

The results demonstrate that most people were "very satisfied" or "satisfied" with the properties of the replica. Therefore, the aim to create a replica that would be as close as possible to the original, while taking into consideration contextual parameters (e.g. touched by many visitors, located in busy gallery, non-hazardous if it breaks, relatively easy to replace, low cost) might have proved correct.

Colour property was rated high, with the vast majority of users being "very satisfied" and "satisfied" with it (31 out of 32) (fig. 60). One (1) participant rated colour negatively (as well as many other properties). Though, this participant as a volunteer has regular access to original museum artefacts and, while recognising the usefulness of replicas, expressed scepticism about digital fabrication for CH interpretation. The majority of participants also rated positively the brightness of the replica (28 were "very satisfied" or "satisfied") as well as reflectance and gloss (fig. 61-63). However, the amount of neutral responses ("neither satisfied nor unsatisfied") rises in these two last properties (9 in each property). Such remark might be explained as a difficulty to understand and rate these properties (see 6.5.4.6) underpinned by the fact that only a small area inside the front rim of the pot is actually glossy (*"It is matt object, so do not expect gloss or reflectance"*).

Most visitors were "satisfied" or "very satisfied" with the replica's size (29 out of 32) (fig. 64). One (1) user rated size negatively. This was the volunteer who was sceptical about replicas. Two (2) people were "neither satisfied nor unsatisfied" with it. One of them was an artist who rated most features neutrally. The other one did not have any relation to CH and, in fact, was

visiting a museum for the first time. This could highlight the uniqueness of perception for each individual which might always be possible to explain. Shape, on the other hand, was mostly positively rated (30 people were "satisfied" or "very satisfied" with it) (fig. 65). Texture received positive ratings too (29 out of 32), apart from the sceptical participant mentioned before (fig. 67). Two people who were "neither satisfied nor unsatisfied" with texture had both a background in CH, one as an artist and the other one as volunteer. The latest one, when further asked, stated that she would want the incised decoration of the replica to feel deeper, even though this is more closely related to shape properties than to texture.

When it comes to the tactile properties of weight, temperature and durability, most participants rated them positively (fig. 66, 68-69). When looking at the charts, though, it can be seen that five (5) people rated weight neutrally. This probably happened because visitors could not compare the replica's weight to the "original" artefact. One participant, however, mentioned that the replica was *"surprisingly heavy"*. Temperature with nine (9) neutral responses could also be perceived as unusual or difficult to rate. So did durability with another five (5) neutral responses too. One of the two people who rated durability negatively mentioned: *"I would like the replica made from something stronger. It seems fragile when tapped."*, while highlighting the interplay of sensorial properties within perception ("…*fragile when tapped*"). Yet, this perception about durability might result from the ceramic-like -and hence fragile- feeling of the object.

Lastly, participants were asked whether the replica could be improved. As already mentioned, one participant would want it made of a stronger material; another one wanted it to be thinner; one visitor said he wanted a protective varnish to be applied on it (he did not know that a matte varnish had already been applied); another wanted the surface to be more glossy; two people noticed minor differences in the incised decoration between the replica and the "original" pot and wanted this feature to be better represented. Generally, there were not any clear patterns that could relate user's rating of sensorial properties with previous professional experience. Moreover, amongst the six people who proposed improvements, three (3) were occupied in CH, while three (3) were not. However, all users who proposed improvements had visited a museum before and would go to a museum at least five (5) times and up to eighteen (18) times a year.

6.5.4 *The expression – perception of the experience*

This section analyses the expression and perception of the experience in a similar way to the first case study (as in 5.5.4). All sources of qualitative data are examined and then analysed by following a mixed approach (see 3.4.11). The analysis is done under the five themes of the RXF (awareness/knowledge, engagement/interest, attitudes, skills, behaviours) while allowing other themes to emerge. Again here, there are overlaps in coding as some of the participants' responses were falling under more than one themes.

6.5.4.1 Awareness/knowledge

Evidence to document the perception of the experience with emphasis on awareness and knowledge emerged from the analysis of the data primarily from the interviews and the open-ended questionnaire questions. In interviews, people were asked whether the experience helped them to discover more information about the exhibit and how. The questionnaire had a general question about the replica pot. The main subthemes and quotes regarding awareness and knowledge are presented in table 21.

Theme: Awareness/knowledge	
Subthemes	**Quotes**
Awareness	*"…he created it with his hands and -you know- the scale of a thing is very much I think influenced by his hands and how it felt to him. So, I think if you can lift it and feel it yourself you get a more of a close sort of feeling of what he would have done when he was creating that thing."* *"…rather than an exhibition on a screen where you can be detached, sort of... you can actually feel him when he was working the bird's neck."* *"I'm not really a big fan of him but I like some of his art and it was great to feel how Picasso might have felt, when he made this pot."*
Making sense of something/broaden understanding	*"I think it gives more of a rounded interpretation of what the pots and things -you know- how he managed to have, the spontaneous way that he managed to create some of these things."* *"Yeah. It gives you more of a sense of how the art like is."* *"I was really pleased to be able to hold the object and I think it added an extra dimension."* *"I learnt more about Picasso as a result of being near this piece for a longer time than I would have if I couldn't touch it. I was happy to be able to touch and hold the replica, it gave me a better idea of what the object is like."* *"…that just gives you a bit more understanding, appreciation."*

Theme: Awareness/knowledge	
Subthemes	**Quotes**
Difficulty in understanding/lack of learning	*"Maybe I didn't learn more from it, but I think it interested me more. It was nice that it was there, but I don't think I would learn anything more than if it wasn't."* *"Um… not really, no. It's just interesting, it was just of interest."* *"I don't know. I haven't really thought that much about it."*
Using previous knowledge/experience	*"I know Picasso, I've seen the museum in Spain… Well I think again it's still on the personal level of the experience with the 3d printer, being an archaeologist and combining the senses again, yeah…"* *"I'm with... being in an art appreciation group we've been listening; we've been talking about Picasso as an artist."* *"…cause I'm interested in ceramics and I really want to look at Staffordshire Pottery, cause I come from around there… But no, it's interesting to see that and touch it and feel it, yeah."*
Learning facts	*"Yeah, yeah, we didn't realise he died so recently, we thought he died before..."* *"Yes. I have learnt more things compared to what I knew. I knew that he had made sculptures, but I didn't know that he had worked on ceramics."* *"I didn't know the information about the potteries that were licensed to make extra replicas of Picasso's work."* *"And now he's in his 60s, very late age, he's influenced now by ceramics. So, quite clearly, I was also, you know, very fascinated at the fact that in a period of two years he created over 3500 different…"*

Table 21: Awareness/knowledge related to the experience of the replica pot and complementing media.

Visitors' comments reflecting awareness and knowledge as effects of the experience are rich. As shown in table 21, some visitors learned new facts about Picasso and his work on ceramics, while others expanded information that they already knew because of past experiences, their occupation and relevant interests. In many instances, people were able to recall information from the video or the printed poster about Picasso, his innovative methods when working with pottery or even mentioned details using previous knowledge about the subject matter.

Most visitors argued that the replica and complementary video helped them to make sense of Picasso's work and become aware of his artistic creation by touching the replica. This happened because they were able to have a closer look and explore the replica, feel like working on the artefact themselves and become less detached from the pot in the display. Few visitors said that the replica did not help them to discover more information about the

artefact or the artist, as they already knew a lot about the subject. Nonetheless, these visitors acknowledged that the replica was something interesting to see and feel.

6.5.4.2 Engagement/interest

People's feedback with respect to engagement and interest is related to enjoyment, surprise, emotions and other inspiring aspects of the experience. Acts and comments related to engagement were firstly "captured" during the observations while the participants were interacting with the replica and complementary media. Most of the visitors' reactions seem to be related to surprise when encountering the replica pot that was available to touch; amazement triggered by the quality of the replica and resemblance to the original as facilitated by 3d imaging and digital fabrication technology; curiosity to explore the replica object in front of the display. Evidence for these types of engagement has also been presented in the social context analysis in section 6.5.2 as part of the interactions between the members of the audience.

Apart from the observational data, further qualitative information was sourced in the interview and questionnaire phase. When interviewed people were asked whether they particularly enjoyed or found anything inspirational when experiencing the 3D printed pot. All subthemes along with representative quotes about engagement and interest are presented in table 22.

Theme: Engagement/interest	
Subthemes	**Quotes**
Using senses	*"So, it's nice because it's -you know- you have sight and we can use our other senses, so we can use another sense, touch."* *"It's very satisfying -you know- really adds to seeing the piece in the case to actually be able to pick it up, to use the handle as it were, to feel the weight..."* *"Because I could feel it, the form, the weight..."*
Reminiscence/memory recall	*"I have seen that in Spain! In pots to drink alcohol."* *"…I think there was an exhibition in Brighton as part of the festival, long time ago, of Picasso's pottery…"* *"It reminded me of a Greek pot. I forgot to write about it. Maybe the colours..."* *"…a friend of my sister is an artist and was working on vases, I think that part of her work has been inspired or affected by Picasso and other artists."* *"…in Beijing, in the National Museum, we build a model in iPad. It is a 3d model, you just can change the directions. But this technology is more... more dimensional... it gives you a real touch of the things."*

Theme: Engagement/interest	
Subthemes	**Quotes**
Feelings	*"It can just give you a chance to touch, to feel the historical things."* *"Right, even though it's not the original, this really touched me personally."*
Inspiration	*"… for me I think it's a kind of like an inspiring thing to take away, to say that, look there isn't a certain age limit where you could take up a different kind of interest -you know- there isn't."* *"I find it inspiring -you know- cause I like Picasso's work and I like the spontaneous way that he works without a great deal of planning. And I think this is something that all creative people need to keep to the forefront… not to sort of have a too fixed idea of the outcome when you start to be creative."* *"I've had mine own art exhibitions before and I like it if I can do something that people can interact with, so it's good when someone else is doing this."*
Enjoyment	*"I liked the sanding that's been done on it, it's nice."* *"I'm a really huge fan of blues! I liked that I was able to touch like an art piece, even though it wasn't the original obviously, but being able to touch it."* *"I really enjoy picking it up and feeling the weight of it and the texture of it… Well, yes. I did enjoy being able to handle it."* *"Yes, I did enjoy the video... and the way that he makes it, yeah."* *"It is good to touch. Objects are usually in a cage."*
Moderate/no interest	*"Well no, I was just interested, that's all…"* *"I don't really see it as a sort of cultural milestone and I think, my honest opinion is the funding could be used to better ways in the museum, for restoring works of art, or something like that. But if it is there, it's another way of people interacting with it… maybe I'm old fashioned."*
Surprise/amazement	*"I first saw it and thought is it a joke? …normally you see… an instruction 'don't touch', that's normal, so 'touch' is a very unusual experience."* *"I thought it was very surprising that it was available."* *"I've just been blown away by it... I've seen pictures and I've seen programs about that but I've never actually… and I really am amazed."* *"Because this is probably the only time I'll ever see anything like this or touch anything like this and it is amazing."* *"I found it remarkable that it was a 3D printed object."* *"Surprisingly heavy and very tactile."*
Imagination	*"I could use it for watering plants… Yeah like watering plants or even a vase!"* *"I don't know what I would ever use it myself... I think that if I put flowers in it, it might look a bit odd… but maybe certain flowers."* *"I was like, oh would I neck in the same way?"*
Curiosity	*"I think I was intrigued… So, why there were two of them?"*

Theme: Engagement/interest	
Subthemes	**Quotes**
	"It's a matter of curiosity to step up and look at it and see what it was about." *"And I just wondered that, is this like a trick or something?"*
Detailed exploration	*"I think it made me notice some of the detail on the original one such as the incised marks on it which weren't quite the same in the replica."* *"I think specially with sculpture objects you can turn the thing around and see it from all the aspects, and often in glass cases you can't."*
Connection to past interest	*"I liked the technology, cause I come from a printing background."* *"I mean I went to college and I've made pots, so I know what it feels like -you know- I've had clay on my hands. This is -you know- it's nothing is it?"*

Table 22: Types of engagement with the experience of the replica pot and complementing media.

As shown in table 22, the experience with the replica and the complementing media triggered a variety of engagements for visitors. Comments of surprise were either related to the possibility to touch, as a new experience in the museum environment, or the quality of the 3D printed replica, as facilitated by digital fabrication technology and its resemblance to the "original". Curiosity is what many people felt when first seeing the replica available in front of the display and were "drawn" to it. Other visitors explicitly mentioned that they enjoyed using more than one senses to explore the pot and this not only enabled a more detailed exploration of the artwork, but also evoked emotional reactions, "allowing" them to feel closer to Picasso and art.

The combination of media was another element that participants mentioned as engaging. Some specifically paid attention to the music of the video or the documentary fragment showing Picasso shaping a similar pot. Others enjoyed artistic aspects of the pot as a result of being able to explore it in detail. Many participants, though, admitted that the replica was the most powerful point of attraction, as it is rather unusual to see an object freely available to touch in front of a museum display. In addition, the presence of the replica made people think and imagine a variety of uses for the pot or even brought back memories related to past experiences and travels. Other visitors felt inspired for their own artistic expression or liked the idea of a replica as a creative way to engage people with their art. Another participant mentioned that he felt inspired by seeing Picasso dedicating himself to a new type of art even at an older age, maybe giving him courage and motivation to start new pastimes explorations.

Finally, a couple of visitors did not demonstrate great interest in the replica. One mentioned that he would want the funding for the production of the replica to be used for other purposes, while another was sceptical due to her past experience with pottery.

6.5.4.3 Attitudes

The attitudinal aspect of the experience relates to someone's values, self-esteem, beliefs and attitudes towards other people, things and organisations. Participants' attitudes as affected by the experience with the replica were recorded through questions about the value of digitally fabricated artefacts in similar experiences. Participants were also asked whether the existence of replicas would work as a motivation to go to museums more often. All representative themes with respect to attitudes can be found in table 23.

Theme: Attitudes	
Subthemes	**Quotes**
Opinions/values	*"I think perhaps it would take away some of the sort of fear of engaging with an object, that you feel that if something happens to the replica it wouldn't be the end of the world."* *"Yeah, I think it's very good to be able to touch something, cause the original you can't touch it (laughs). They're just kept in a cage or behind a screen and you can't touch them. It's nice to be able to touch."* *"Well, I think so much is behind glass and we can't, I mean I'd love to have touched some other things in the other gallery but couldn't. But seeing that it is by Picasso -and everybody knows Picasso- it's a good starting point for people."* *"I think it's a very economical and efficient and… um important way that people can have a hands-on experience with just -you know- things are behind glass and you can't touch anything."* *"Well, the fact that you can touch, the fact that you can hold it yourself. I don't know the cost, if the cost is legible for us to then -you know- hold the materials, I think is very valuable."*
Ethical considerations	*"But it's also scary because, like you say if technology can do that, is there any use for somebody being -you know- an artist doing one-offs or something?"* *"Nothing is wrong with the replica, but if displayed (people) should be informed that it is a replica."*
Attitudes of/towards/regarding organisations	*"I think it would, yeah, if you had the opportunity to look at things in that way. It probably would make me visit more and probably come to see more."* *"I think having different techniques to engage people. It's really helpful, so having the video, having the thing that you can touch… there is something I've noticed in the new gallery, the archaeology gallery, they're using all*

Theme: Attitudes	
Subthemes	**Quotes**
	different kinds of ways to communicate with people, which I find really effective." *"Yeah, I think anything interactive is a good thing and there is a move towards that in museums, isn't there? Wherever you go now there's more interaction."* *"…if these things were available, cause it sort of deformalises the whole museum thing, in a sense it makes it more touchy-feely thing."* *"I must say I've not had the experience with that before but when I see that I can touch it, I noticed that I'm drawn to it. So that part, that's nice, but still I'd like to go to a museum even though I can't touch paintings."* *"I'd probably was going to go there anyways but I would spend more time with the… with these objects, sure yeah."*
Attitudes towards/about other people	*"…it would be a lot more interesting for people to -you know- get to know objects in an intimate way, rather than seeing them behind glass and feeling a bit removed in a museum experience..."* *"I think it's valuable and I think it would be extra valuable for children, cause they're always taught don't touch this, don't touch that…"* *"I enjoy coming to museums but I'm acutely aware as a child not enjoying them, but I think this could fill that gap from a children's exhibit through the sort of wilderness of adolescence, to being an adult…"* *"Obviously there ought to be a great advantage for people who are partially sighted or blind, maybe a great advantage for people with learning disabilities or for children, so yes, lots of advantages."* *"I think it makes it more interesting in kind of… is valuable for people that may not be so interested in art and design, to have something there."* *"I think it's a great idea and I think it would draw many others to art."*

Table 23: Attitudes related to the experience of the replica pot and complementing media.

As evidenced in the comments, most participants emphasised the lack of tactile engagement with artefacts in museums and mentioned that they would value and appreciate hands-on opportunities. One participant characteristically described replicas as means to take away the *"fear of engagement with objects"* that might originate in their value and fragile nature, enhanced maybe by the "no-touch" museum environment. Another interesting opinion was also expressed by two participants who mentioned that replicas could constitute efficient and financially feasible ways to support interpretation and visitor engagement; something further related to the feasibility of production and multiple replication by means of digital fabrication.

When it comes to attitudes regarding organisations, most visitors commented that 3D printed objects would motivate them to go to museums more often (22 out of the 32 participants),

while some also recognised current efforts of the sector to promote interactivity and alternative means of engagement with heritage. A small number of visitors (6 people the majority of whom did not have a professional background in CH) said that they would go to museums anyway but acknowledged the usefulness of replicas or mentioned that they would make their visit more interesting.

As far as it concerns attitudinal data towards or about other people, many participants mentioned that 3D replicas would be particularly useful for children, young people, visually impaired visitors and people with learning disabilities. Another participant highlighted the intimate connections that replicas could promote between visitors and exhibits, while two people emphasised the importance of replicas as ways to "draw" people to art.

Lastly, few users mentioned ethical considerations about replicas (part of them had a CH background). Those people generally liked the idea of replicas but would not want everything to be replicated in a museum, as it might diminish the "uniqueness" of artwork and make objects less "special". One participant further emphasised honesty by suggesting that CH organisations should always inform visitors when a replica is exhibited (also see 6.5.4.6).

6.5.4.4 Skills

Observational data as well as data from the interviews evidence that the experience of exploring the exhibit with the support of the replica, video and printed information constituted an activity, where people used tactile, visual and intellectual and often communication skills. Visitors' comments also witness they felt connected to other people's skills; in this instance, the artist who created the bird pot. Representative comments revealing skills' development and deployment are presented in table 24 and mostly originate in answers regarding knowledge/awareness and engagement/interest (see previous sections). In an effort to record feedback related to communication skills, visitors were asked whether they would talk to others about their experience with the replica pot and complementing media.

Theme: Skills	
Subthemes	**Quotes**
Tactile skills	*"I really enjoy picking it up and feeling the weight of it and the texture of it."* *"I was happy to be able to touch and hold the replica, it gave me a better idea of what the object is like."*

Theme: Skills	
Subthemes	**Quotes**
Communication skills	*"Sometimes, like, if my friends have interest in Picasso… it's a cool thing because somebody replicated the things from Picasso, you can touch it… my friends might be crazy about it!"* *"Definitely. I' going to tell my friend who has a 3d printer all about it."* *"I'm already going to talk about it. I know someone with a 3d printer!"*
Intellectual skills	*"I didn't know the information about the potteries that were licensed to make extra replicas of Picasso's work."* *"And now he's in his 60s, very late age, he's influenced now by ceramics. So, quite clearly, I was also, you know, very fascinated at the fact that in a period of 2 years he created over 3500 different…"*
Combination of skills	*"It's very satisfying -you know- really adds to seeing the piece in the case to actually be able to pick it up, to use the handle as it were, to feel the weight… um to look at the colour and the grooving on it."* *"So, it's nice because it's -you know- you have sight and we can use our other senses, so we can use another sense, touch."* *"I liked the fact I could lift and feel the pot while looking at the original."*
Connecting to other people's skills	*"So, I think if you can lift it and feel it yourself you get a more of a close sort of feeling of what he would have done when he was creating that thing."* *"…because he created it with his hands and -you know- the scale of a thing is very much I think influenced by his hands and how it felt to him."* *"you get the feeling that that could have been worked as well and it's just makes it a very interesting concept."*

Table 24: Skills related to the experience of the replica pot and complementing media.

Looking at the comments above, it becomes clear that people enjoyed using their tactile skills to better explore and appreciate the exhibit. Other people emphasised the synergy between sight and touch, enabling them to have a more holistic experience of the pot. Interestingly, the replica not only directly affected the visitors who interacted with it; it also "allowed" them to connect with Picasso and his artistic methods. Further quotes, with factual information that people learned through the interaction with the replica and complementing media, demonstrate the impact of the experience at an intellectual level aiming at enriching knowledge and enhancing thinking. Finally, when visitors were asked, whether they would talk to others about this experience (communication skills), most of them responded positively (27 out of the 32 participants) and mentioned friends, family and colleagues.

6.5.4.5 Behaviours

The behavioural aspect of the experience is closely connected to actions, possible changes in people's lives and progress as the outcome of such experience (e.g. further skill acquisition and learning). Most behaviour related statements were collected during the interviews from general introduction and ending questions, when people were asked to share their opinion about the whole experience and add further thoughts. A great number of behavioural data were also gathered from answers related to attitudes (presented in 6.5.4.3). Behavioural subthemes along with characteristic quotes are presented in table 25.

Theme: Behaviours	
Subthemes	**Quotes**
Future development	*"I think you should go forth with this. I think is really important and a really intelligent marriage of past and present."* *"I mean just like hopefully, like one day, I can see more of it."*
Change in accessing information and CH organisations	*"Technology can show us new things from the collections like... things we cannot touch and the things inside the glass and the technology can satisfy… it can give us a chance to get in touch, very close to the replicas and this is my opinion, I think it's good."* *"So, I think it's a really important technology to use to bring the past and the present together."* *"…people can touch it and feel it without actually thinking 'I have to be very cautious'."* *"But the experience of seeing it 3D is infinitely better than a photo."*
Change in professional practices	*"Yeah, I can imagine that for museums which can't afford the original, this is an alternative."* *"I guess it would be good to -you know- bring people together in a group and pass it around and talk about the object and see what you think of it."* *"Also, it may be useful for people who are archiving work, to have perfect copies cause if it is ever destroyed it could be reproduced in the finest details -you know- as a facsimile."* *"Nobody needs to know… it's safer for the museums to keep the artefacts in their stores and have the 3D printed stuff at their displays and no one would know."* *"I don't know if this is a point, but at some point, selling these would perhaps bring an income for the museum?"* *"I could see it in the future as a way of maybe as a gimmick which could become a function, like a standard function of a museum. I mean right now this is a gimmick but, in the future, it might become a standard thing."*
Participation	*"I think it gives you more of an experience of being part of what the artist was doing…"*

Theme: Behaviours	
Subthemes	**Quotes**
	"But if the visitors are allowed to like hold it or something then I think you can be more related to the artwork yourself."
Learning desire or progression	*"I was just saying, you know, how very shapeful it was. Could I ask a question, what is this exposed object (she means what is it made of)?"* *"…it sparks questions about the making of the original one too as well."* *"So, this is how this was made by 3d printing? And how does it have this… the right kind of texture?"*
Action as result of the experience	*"Yeah, probably I will because I'm planning to do some more tours in Brighton and I hadn't thought about the museum in the tour, although I have been before, but I haven't been for a while. So, I think things have changed, so yeah."* *"I would talk to my daughter who's also a member of the art group and when I get home, cause she would be very interested in it."* *"I'm already going to. I know someone with a 3d printer."* *"My husband he has studied art history and he's working in heritage conservation. Therefore, sure I would talk to him, it would be nice."* *"I can't wait to tell my son. He is a carpenter. He works with wood."*

Table 25: Behaviours related to the experience of the replica pot and complementing media.

As seen in table 25, people expressed their hope and desire to see more replicas in future. In more detail, people described replicas as means that can change the way visitors experience CH, by: connecting history to present; bringing visitors closer to artefacts; offering interpretation which is better than other "traditional" media; while removing somehow the fear of damaging the original artefacts (if these were available to touch). Visitors also suggested that digitally fabricated replicas could be a solution when museums cannot afford to exhibit original artwork (through acquisition or loan). Replicas could further be used to spark conversations around art during workshops and other engagement contexts. Some visitors mentioned the commercial value of replicas as a source to generate income. A rather "radical" idea about the way replicas could change standard heritage practices came from a participant, who proposed removing original artefacts from museums and exhibit replicas instead without letting people know, as a measure that would protect the originals.

More behavioural data reveal that digitally fabricated artefacts provided a sense of participation and involvement with the creation of the pot as well as the experience of it in the present time of exploration. Additionally, the replica seems to have intrigued people to learn more about the making of the original pot and the production of the replica. Lastly,

some participants mentioned that they would take further action after exploring the replica, such as including the museum in organised tourist visits, talk to tech or art enthusiasts or people who are involved in crafts.

6.5.4.6 Other themes

A set of particularly interesting themes that emerged through the qualitative analysis are presented here. These themes resulted from the RXF-based analysis and deployed methods, but highlight noteworthy aspects of the experience or are more generic/abstract and therefore are presented here (see also 8.4.1).

Firstly, one of the remarks made is that people occasionally expressed **difficulty in rating** some of the sensorial properties of the replica. As the target group consisted of adult users with vision, it was noticed that properties such as *reflectance* and *gloss* were not always understood by everyone. *Temperature* seemed a property to surprise some of the participants too. Those asked for further clarifications (e.g. the meaning of the word) when filling in the questionnaire. Some of the users' quotes revealing some difficulty when rating these properties were:

"It is matt object, so do not expect gloss or reflectance."

"It is difficult to rate it if you don't have the original one under the same light."

Assigning to the replica some kind of inherited value from the original artefact and perceiving it as a **fragile object** is another noticeable aspect of the experience. As already mentioned, (see 6.5.4.2 and 6.5.4.3), visitors' reaction might be related to the fact that touching artefacts in a museum is relatively unusual and hence a surprising potential for many. Some of the users' characteristic comments were:

"I was very hesitant; I couldn't believe I could touch and then kept touching until I got scared in case I would break it!"

"I was also a little bit worried that -you know- like… I would be like really careful but I'm not so sure… like -you know- what if like it's broken? Do you have, like a spare one?"

"When I first came to it, I didn't know that it was a 3D replica. I thought that it may be the real object and I didn't want to touch it… I think there could be issues when… if it was a big exhibition, the 3D objects could get very grubby if lots of people were touching it."

Such comments, in conjunction with quotes that evidence a certain fear about the object's safety (*"I saw that, and I touched it and I was expecting it to go BOOM!"*), reveal further security considerations. In the frame of this research, the replica of the Pot Oiseau was "guarded" by the researcher. To allow free exploration without worrying about the safety of the object, security arrangements would be needed otherwise. However, safety considerations seem context dependent, as other examples of replicas' deployment witness (see examples of "independent" pieces of a replica puzzle, as well as replicas which are attached on surfaces within the Archaeology Gallery of BMAG in Chapter 7 and "independent" replicas used in educational programmes in 2.4.3).

Another interesting theme that emerged from the data analysis refers to the importance of the **"accuracy"** of the replica to the original. Even though the replica was designed to be as close as possible to the original, while taking into consideration contextual parameters and the visitors were asked to rate it without implying any intention for comparisons, it was noted that people tried to compare it to the original anyway. Their comments reveal how significant "accuracy" has been for them as well as their tendency for comparisons:

"It's very nice to have something that's very close to the original."

"I really was glad to be able to touch it and lift it and compare it with the original one in the case. It was… In many respects it looks very very similar, but I could notice some differences, but it was good to experience that."

"I was impressed by its perfection, in a way."

"I liked how the replica and the pot… the original itself was very identical."

"it's kind of very interesting because I thought it was ceramic, while looking at the interior it looks ceramic. The exterior looks like pottery… cause you want to see does this shoe fit the same as that?"

The investigation, though, of this "accurate" replica is directly correlated to the theme of **authenticity**. As such, authenticity -and consequently whether people mind that the interpretative object they encounter is not an authentic one- arose in many discussions. Some of the participants' comments reveal scepticism:

"The replica is amazing. However maybe something is lost if that is made by a machine and different materials. The essence of the human touch."

"For the negative ones, people might say these guys have used technology to create some fake, not real ones (he means objects)."

"No, I don't think people will go to a museum where they know it's all replicas which they can touch."

"I wouldn't like too much for it, because I think the thing about a museum is, you're actually looking at the real thing, even if it's behind glass. I mean if you could touch this... yeah, all well and good, but it's not what you're going to the museum for. The museum is a special place."

While others were positive or did not worry that much about authenticity:

"No, I didn't mind that it was a replica."

"No, I think it is all right (that it is a replica). I think that just that you can touch it, even if it's a replica and not the real thing."

"To see just how authentic it was, but being able to pick it up, touch it, you know, get a close outlook at the 3D print and also Picasso's work and you cannot tell the difference. They are almost identical."

"Yeah, it allows them to -you know- it's like… it's… this is the object, alright it's a replica but that's not the point. The point is, this is the end product -you know- get them close to that end product of how things were, how the materials were put together and this is it."

"I like that they were both there, like… If I were to see a vase like that, I would like the actual thing to be there and then also a replica."

By looking at the representative quotes above, it becomes clear that many visitors did not mind that the object they interacted with was a replica. In fact, these people seemed to prioritise: the possibility to touch as a new venture in the museum; how identical or even "authentic" the replica was to the original; and the co-existence of original and replica next to one another. On the other hand, some people did not like the fact that a replica might not have been made from the same materials as the original artefact. Those people worry that the "soul" of an object is lost or that artistic effort is threatened somehow by the process of fabrication. Not surprisingly, comments related to materials and arts came from people with professions and background within the CH sector.

Lastly, a theme that emerged both from people who were in favour or sceptical about replicas is that of **honesty**[44]. Some of their quotes were:

"So, it depends on whether you give the information to the citizens. If they have the information, they can decide if they are good things or bad things (the replicas)."

"Nothing is wrong with the replica, but if displayed (people) should be informed that it is a replica. You ought to be told."

In this sense, people believe that CH organisations should inform visitors when a replica is exhibited or provided to touch. Then, they will be able to decide whether this is something they approve or not.

6.6 Conclusions

The results of this case study corroborate some the phenomena that have already been described in visitor research, such as the demographics of museum visitors, the social nature of a visit as well as the fact that most people who came to the museum had visited other CH venues in the past. Apart, from these general remarks, the research highlighted that in most cases people have not had the opportunity to touch an artefact before and not all of them had experience with technology in CH contexts (especially the older ones). Data further demonstrate that people have different interests, expectations and "carry" a variety of past experiences when coming to a museum and in some instances these have affected their responses when evaluating the replica and experience with it (e.g. some mentioned seeing replicas in the New Archaeology gallery, others came to do artistic work and were hesitant towards replicas due to "lack of human touch", others mentioned seeing similar examples in museums afar and more).

The interactions that were triggered by encountering the replica are also justified by data (social context). Hence, the replica sparked discussions about Picasso, 3D printing and the resemblance of the fabricated artefact to the original, to name a few. It also prompted

[44] With the exception of one participant who, as mentioned in 6.5.4.5, proposed removing original artefacts from museums and exhibiting replicas without letting people know.

expressions of surprise due to the possibility to touch and physical movements, such as bringing people to show them the replica, whistling into it or posting photos on social media.

As for the physical context of the experience, a number of visitors explicitly stated that the replica is what attracted them to the whole exhibit. Curiosity to find out what the freely available object in front of the display was, attracted them to Picasso's pot. In this sense, the replica worked as the "hook" to evoke interest and engagement. As Csikszentmihalyi and Hermanson (1995) mention *"it is by appealing to this universal propensity that museums can attract the psychic energy of a visitor long enough so that a more extensive interaction, perhaps leading to learning, can later take place"*. Simultaneously, though, it was noticed that many visitors were reluctant to touch the replica and when they did, they were "modest" in their physical interactions. Yet, the replica did not distract visitors from paying attention to the original artefact and certainly increased the time spent in front of the exhibit; something that might lead to learning as Csikszentmihalyi and Hermanson (1995) described.

When examining the sensorial properties of the replica, most people positively rated both the visual and tactile properties of it and tended to compare the replica's properties to the original pot. However, some users expressed difficulty when rating the reflectance, gloss and temperature properties which might have been perceived as unusual to evaluate. Apparent differences or patterns between those with a CH related profession and those without are not obvious in ratings. A minor observation is that, in some cases, those with a CH background preferred to give edge positive ratings whereas those without it gave mixed positive ratings (e.g. Shape: *CH background* - 10 very satisfied and 0 satisfied | *No CH background* - 12 very satisfied, 8 satisfied). Similarly, those who proposed improvements for the replica came both from CH related and non-related backgrounds. Nonetheless, they were all relatively frequent museum goers. Some improvements were related to shape properties of the pot (i.e. incised decoration) as well as durability, even though this last one might be related to feeling the replica as being made from clay.

Furthermore, the analysis of the qualitative data highlights the potential that 3D replicas have within experiential frameworks. The 3D printed pot seems to have enhanced effects such as: learning of facts about the original artwork; appreciation of the artistic work; awareness of the creative process; triggering of people's interest; enjoyment when feeling and exploring the object in detail; recall of memories; emotional connections to the artwork and beyond;

and deployment of skills. Many participants stated that they would want to see more replicas in museums in future and this would motivate them to visit CH settings more often. Replicas also support the deformalisation of cultural experiences, as the fear of engagement with artefacts decreases through touch. Artefacts and exhibitions, hence, become more accessible and replicas contribute towards the democratisation of CH. Replicas can also assist audiences, such as children and people with impairments to better experience CH. They also have the power to support management processes in the CH sector and even bring new sources of income to organisations.

Finally, most visitors did not seem to mind that the replica was not an authentic object and appreciated the fact that they could touch an almost "accurate" or identical to the original object while looking at the pot in the display. A certain scepticism about authenticity was expressed by few visitors and was mostly related to the loss of craftsmanship or "human touch" and the "soul" of the artefact. Nevertheless, most of those people did not deny the usefulness of replicas and emphasised the importance of honesty when CH organisations deploy replicas as interpretative means in experiential frameworks.

6.7 Summary

This chapter was dedicated to the second case study of the research, where a 3D printed replica of the Pot Oiseau along with digital media was presented to the visitors of the BMAG. The first part of the chapter detailed the design of the case study and then the evaluation of the CH experience followed. In this case too, the RXF guided the collection of data and provided a structure to analyse the quantitative and qualitative results under the context classification and the basic expression/perception themes.

The results of the case study illustrate how unique an experience with a replica can be for visitors, who might have had different backgrounds and experiences in the CH context and beyond. Thus, even though quantitative data about the sensorial properties of the replica do not seem to demonstrate great variations between people with a CH background and those without it, the analysis of qualitative data often resulted in themes that relate to memories, past knowledge, experiences and so forth.

Some of the significant outcomes of the study evidence that people are not accustomed to deploying touch in an exhibition environment; how surprised they become when objects are available to touch; and how powerful replicas can be to attract their curiosity or interest and

trigger a variety of engagements with CH. Such engagements have the potential to deformalise and democratise CH, focusing mostly on the importance of the experience itself and not the mere value of the object on offer.

The following chapter presents the third and final case study of the research along with the analysis of its findings.

7 Chapter 7: Case study 3 – Saltdean urn puzzle

7.1 Introduction

The seventh chapter of this thesis is dedicated to the third and final case study of the research. The case study involves families with children aged between six (6) and twelve (12) years old interacting with a full 3D printed puzzle-pot replica representing a late Iron Age funerary urn from the new Elaine Evans Archaeology Gallery of the BMAG.

The chapter describes how the study was planned in collaboration with the RPM officers. It then includes information about the target audience and the chosen artefact, as well as the development of the puzzle-pot replica, while considering technology and available resources. The chapter also discusses the evaluation process with regards to data collection methods, the pilot study and lessons learned from the first trials. Finally, the chapter presents the findings of the evaluation, following the theoretical proposition of the RXF (Chapter 4).

7.2 Planning the study

The third case study investigates how a target audience that consists of adults and children (family groups) responds to the experiential framework of a hands-on puzzle-pot activity that deploys 3D technologies and digital fabrication for its design and production. The study explores how families behaved during the activity and examines their feedback based on the theoretical proposition of the RXF (Chapter 4).

The main purpose, target audience, ideas about the object to replicate, the purpose and nature of the activity, available resources and so forth, were first considered at the planning stage of the case study, in collaboration with all involved stakeholders (similarly to the previous case studies and as guidance in 8.4.2.1 describes). Therefore, a funerary urn, from the Archaeology collection of the BMAG, was chosen in order to design an activity that would engage young audiences in assembling a digitally fabricated 3D printed puzzle-pot. The selection of the specific artefact was the result of a series of discussions with the curators of Archaeology and the designer of the BMAG. Planning the case study around this artefact coincided with the process of designing the new Archaeology Gallery which is the latest addition to the museum's permanent exhibitions and was inaugurated in January 2019. The 3D puzzle constitutes a permanent exhibit incorporated in the new Archaeology Gallery. The puzzle is placed along with local findings of the Iron Age period close to the original artefact.

Hence, the objective of the case study would be to produce a puzzle-pot to primarily support children and their families in having an interactive experience with a heritage artefact in the form of an activity or game, without excluding wider audiences (see also fig. 70 about the target audience of the gallery). By assembling the puzzle, visitors could experience a challenge, such as reconstructing ancient pottery from a group of shards and potentially engage with the exhibit, its physicality, function and history.

7.3 The development and design of the study

This section presents the contextual information, the "ingredients" of the case study, i.e. the Archaeology Gallery and the chosen artefact, the target audience and the design and development of the hands-on puzzle-pot activity, as well as information on the technology and available resources (see also 8.4.2.1 on the deployment of the RXF to facilitate the design of a replica experiential framework).

7.3.1 The Elaine Evans Archaeology Gallery

The Elaine Evans Archaeology Gallery is the newest addition to the array of permanent exhibitions of the BMAG. The Gallery, launched in January 2019, is the result of local efforts to present the archaeological heritage of Brighton and Sussex, through the exhibition of key artefacts from the Archaeology collection of RPM. These artefacts were kept until recently in storage, as only a small part of the collection was exhibited at the Hove Museum in a rather fragmentary way.

The Archaeology Gallery targets families and young audiences in order to introduce them to local history, by showcasing aspects of life of the local inhabitants of Brighton and Sussex (fig. 70 left) (Royal Pavilion & Museums, 2019). Thus, it showcases artefacts, human remains, facial reconstructions, physical maquettes of settlements, images and audio-visual interpretative content demonstrating advancements in human history (e.g. making fire or stone tools) and everyday practices (e.g. dyeing fabrics or writing on wax tablet) (fig. 70 right).

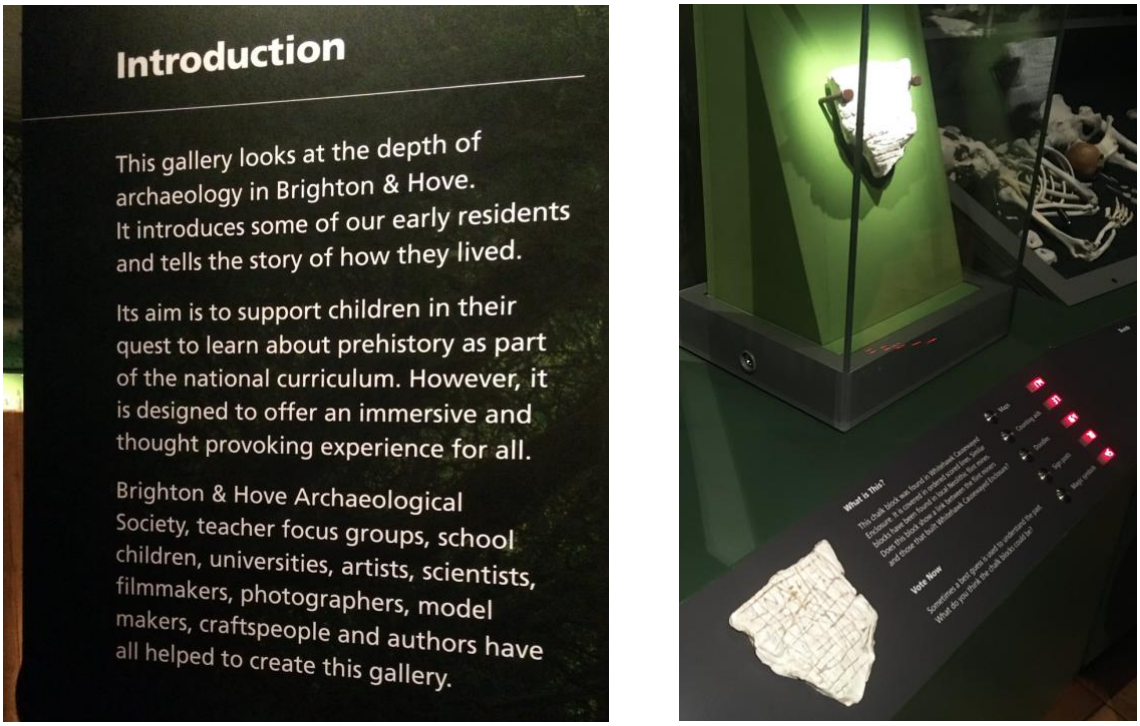


Figure 70: Introduction text in the new Archaeology Gallery (left) and example of the interpretation means deployed in the Archaeology Gallery including 3D printed replicas (right).

The Gallery's highlights are seven forensic 3D facial reconstructions that represent local people from different periods, starting from the Ice Age and then proceeding to the Neolithic Age, Bronze Age, Iron Age, Roman Period and Saxon Era. The skulls that constitute the base for each facial reconstruction have also been 3D printed. Likewise, the Gallery features -apart from the puzzle-pot- more 3D printed artefacts for visitors to touch. All 3D replicas and skulls have been scanned, processed and printed by the members of the Digitisation Lab of the UoB, including the author this thesis (Digitisation Lab - University of Brighton, 2019).

7.3.2 Saltdean funerary urn

The chosen artefact, the funerary urn (fig. 71), comes from Saltdean, a coastal area near Brighton, UK. The pot was found on the edge of a chalk-cliff in 1910 by a boy playing in the area. The boy, who had visited the Brighton Museum in the past with his class, understood that the pot was of archaeological importance and he carefully removed it, with the help of a friend, from the face of the cliff. He then took the pot home and subsequently the urn was transferred to the Hove Archaeological Club.

Figure 71: Different views of the Saltdean late Iron Age funerary urn.

The urn has a globular shape, a short neck, medium mouth and round rim. It also features a characteristic concave kink in the centre of its base. The pot has curvilinear designs which are usual in Sussex in the two centuries BC, before the arrival of the Romans in 43 AD. The colour of the urn is mostly brown, and it seems that burnishing[45] had been applied to its surface to give it a "leathery" appearance. When the urn was found, it contained human cremated bones, possibly from a young person, along with cremated pig bones (Toms, 1912).

The Saltdean funerary urn has been recognised as a late Iron Age pot (probably 1st c. BC) which was thrown on a wheel. The pot possibly reflects influences from Belgian tribes and people from Brittany who had moved into the area and introduced the use of the potter's wheel in south Britain. Even though there have not been any findings related to the existence of a settlement near Saltdean, it is possible to hypothesise that a small Iron Age farming settlement could have been built there overlooking the cliffs and sea. After all, there is archaeological evidence about Iron Age settlements in the wide area of Brighton. Some of the most important are: a. the Hollingbury Hill Fort, built around 250 BC with a defence wall made of chalk rubble and timber and a deep ditch in front of it; and b. the Devil's Dyke Hill Fort, which provided security for local people. Other settlements existed in Kemptown, Newhaven and Coldean (Adkins and Adkins, 1982; Cunliffe, 1978, 1995; Harding, 1974; Toms, 1912).

[45] Burnishing is the process by which the surface of a pottery object is polished using a smooth tool such as a bone spatula, a stone or something similar before the pot is fired.

7.3.3 Target audience

The target group for this case study are families with children between the age of six (6) and twelve (12) years old. This age frame is considered as appropriate in terms of integrating one type of activity as interpretative means can be different for younger or older children groups (Tilden, 1977, pp. 47–54).

Children, whether they visit with their families or school have been recognised as an important part of most CH organisations' audiences. Children appear to be amongst those who can benefit the most from CH experiences with the deployment of replicas (Cabral and Justice, 2013; Miles et al., 2015; Neely and Rozner, 2015). Furthermore, official numbers (in the *Overview of data in the Museums, Libraries and Archives Sector* (Matty, 2004)) confirm that most people who visit a CH institution in the UK belong to a family group or a school group. In addition, 2018-2019 statistics reveal that there were 8.4 million child visits to the sponsored museums and galleries in the UK (Department for Digital Media Culture and Sport, 2019a). According to the *Museums' Audience Report* from *The Audience Agency* (2018) and data coming from one hundred and five (105) UK museums, 35% of the audiences that attend a museum come in family groups.

The BMAG itself has high numbers of families and school children visiting its premises (see also section 3.4.9). Moreover, a survey realised in summer 2015 to record visitors' opinions on the potential to exhibit the archaeological collections of the museum -hence before designing the new Gallery- revealed that people would be interested in hands-on children's activities (Royal Pavilion & Museums, 2015).

7.3.4 Development of the 3D puzzle-pot replica

7.3.4.1 Design requirements and challenges

The main design requirements with regards to the 3D puzzle were agreed between the researcher, the exhibition curators and the designer or the RPM taking into account design guidelines about children's puzzles (Smith, 2002). These included:

a. to have the urn height scaled-up to around 30 cm (the rest of the dimensions were scaled-up proportionally);
b. to have a thickness of around 1 cm for each individual piece, as this was found suitable for children;

c. to have approximately 10 pieces to assemble the puzzle. Thus, pieces should measure at least 5.8 cm across, as 6-8-year-old children (the youngest children of the targeted age group) can handle pieces of this size;
d. to design a core which would be attached to a rotating wooden plate so that the user can easily spin the puzzle core to facilitate assembly (fig. 72);
e. to enable attachment of the individual puzzle pieces to the core via magnets. The magnets are inserted in blind holes in the puzzle pieces and in the solid core;
f. to cover each individual piece in a plaster-like finish and paint it to disguise the magnets, provide better texture feeling and a more realistic appearance.

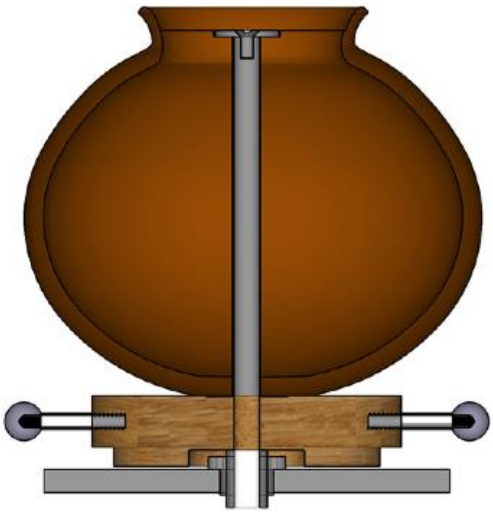


Figure 72: Design of the puzzle core on its rotating base. Design courtesy of Alex Hawkey.

When discussing with the RPM officers, it was acknowledged that such requirements could be partly addressed by using conventional production methods. However, it was deemed that digital fabrication would enable to future-proof the exhibit and replace parts easily in case this is needed.

As far as it concerns the digital fabrication of the puzzle, this can be achieved by different methods and tools. Some of the main challenges when creating a replica of this type include: acquiring the shape of the pot and reconstructing a "watertight" (printable) model; generating the puzzle pieces with interlocking parts; modelling a core to provide clues about the overall shape of the puzzle-pot; and facilitate assembly by attaching the pieces to a core.

Figure 73: Puzzle-pot from the Bristol Museum & Art Gallery (UK). Photo courtesy of Andrew Maxted (left) and puzzle-pot from Rezé Museum (France). Photo courtesy of Theophane Nicolas (right).

Similar examples of pottery puzzles in other museums are shown in fig. 73. Pottery artefacts are amongst the most usual findings in excavation sites around the world. Thus, reconstructing a pot from its shards is a problem often faced by archaeologists and conservation staff and resembles the action of assembling a puzzle. These puzzle examples require a static element (the core) that usually provides a clue of the overall shape of the pot. Magnets on the surface of the core and on each puzzle-piece might also help to assemble the puzzle. The puzzle of the Saltdean pot features some similar elements, while deploying a semi-automated digital workflow to generate puzzle pieces with predefined holes on them and on the core for magnets to facilitate assembly.

7.3.4.2 Workflow for the production of the 3D puzzle-pot

The workflow for the production of the 3D puzzle-pot replica includes all the steps that were taken in order to produce the puzzle while taking into consideration the design requirements. The process included work both with the digital files and the physical 3D printed parts. The final result is a product of collaborative work between the researcher, colleagues from the Digitisation Lab who developed the algorithms for the semi-automated puzzle generation, the technicians at the 3D printers' lab of the UoB, as well as the curators, designer and artist of the RPM (see also 1.8 for the received support).

The workflow for the puzzle production has already been detailed in published work (Rodriguez Echavarria et al., 2020; Rodriguez Echavarria and Samaroudi, 2018)[46]. Therefore, only a short list of the steps will be included here along with some representative images. In short, the steps for the puzzle production were:

- 3D scanning of the Saltdean urn and modelling in computer graphics software to acquire a watertight and thick pot shell along with an internal core (fig. 74);
- fracturing the shell into puzzle pieces following a semi-automated approach in Computer Aided Design (CAD) software (fig. 75);
- generating matching attachments or holes at the back of the puzzle pieces and on the core (in CAD) to insert magnets (fig. 76);
- 3D printing and post-processing steps to clean, sand, paste core and base, insert magnets, cover and paint. Then, the pieces and core were given to the RPM artist to paint the pot and make it look as close as possible to the original one (fig. 77).

Afterwards, the final interactive exhibit was placed at the museum gallery (fig. 77 bottom right) in the area that is dedicated to the Iron Age.

Figure 74: Reconstructed urn (left) and core (right).

[46] Available here: https://research.brighton.ac.uk/en/persons/myrsini-samaroudi/publications

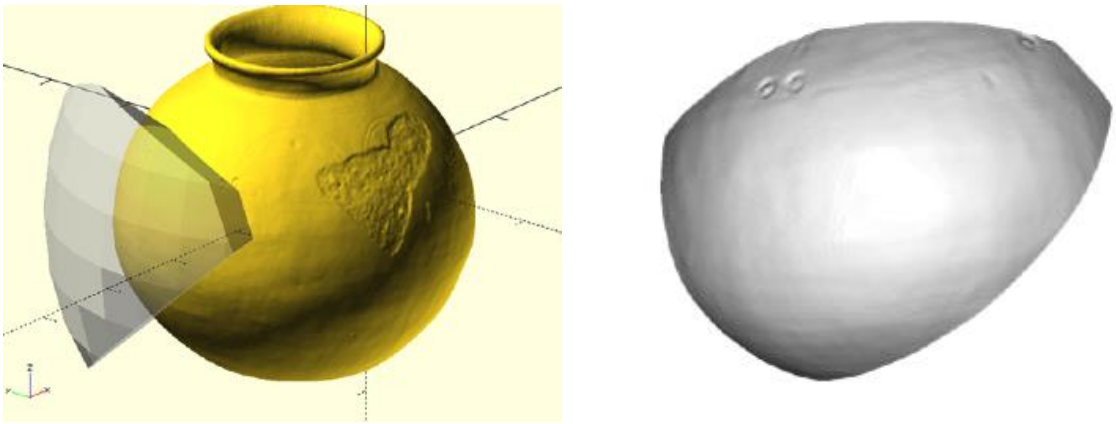


Figure 75: Fracturing the urn in pieces (left) and resulting piece (right).

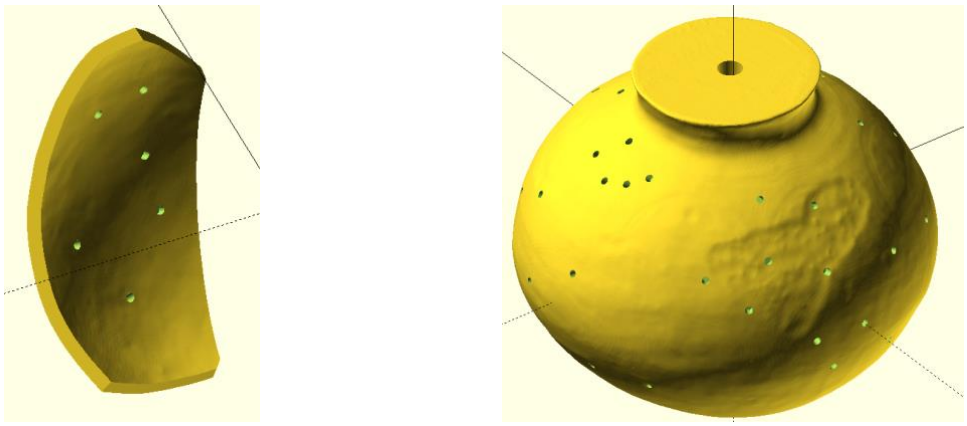


Figure 76: Puzzle piece with holes (left) and core with matching holes to place the magnets in (right).

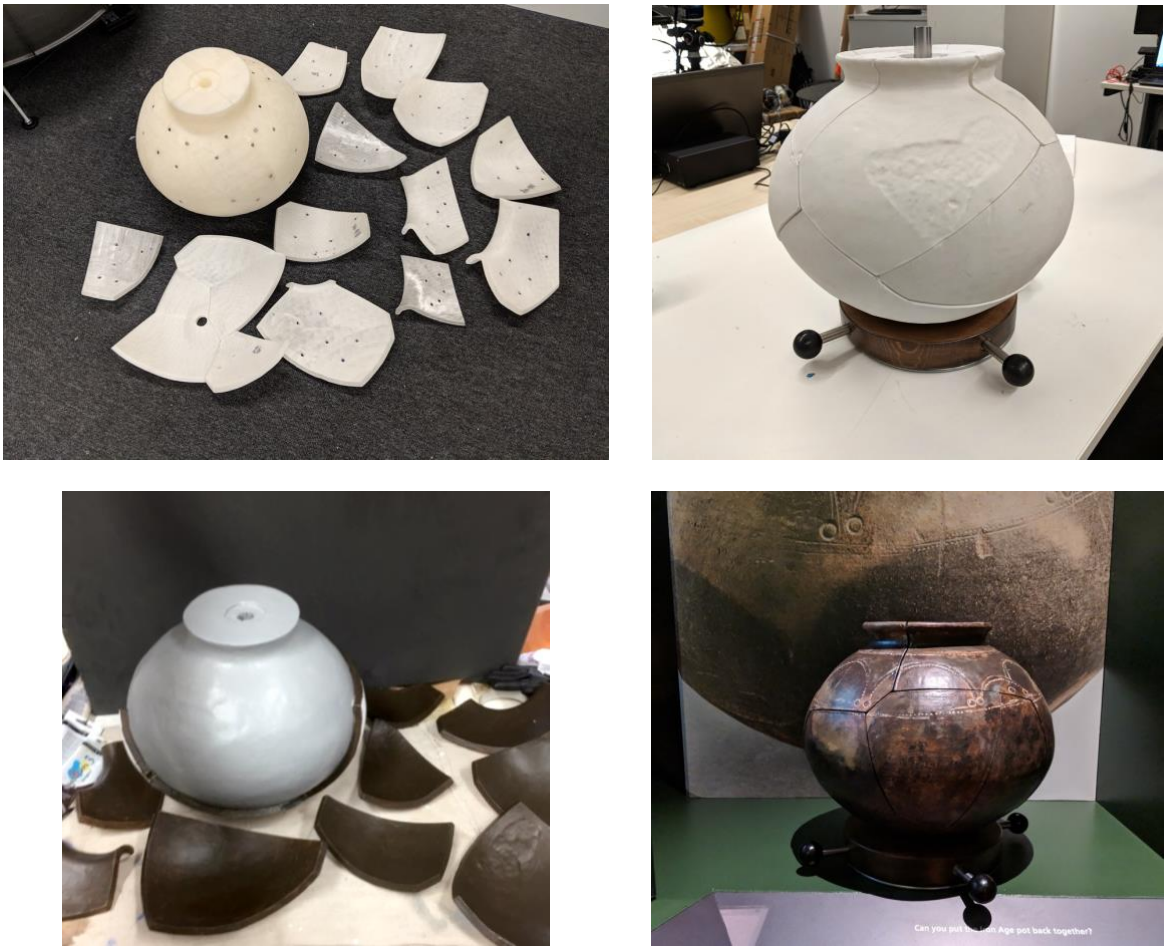


Figure 77: Printed puzzle pieces and core with magnets (top left); post-processed puzzle pieces and core with ceramic-like texture (top right); painting puzzle pieces and core-photo courtesy of Russell Webb (bottom left); the final puzzle-pot activity in the Archaeology Gallery of The BMAG (bottom right).

7.3.5 Management, resources and technology

Producing the puzzle-pot has been a rigorous process that involved constant communication and collaboration between the researcher, the curators and designer of the BMAG, as well as colleagues at the UoB. The artefact was scanned by the researcher and support was provided by the team of the Digitisation Lab when editing the 3D mesh and producing the core for the puzzle. The same team worked on the semi-automated algorithms to generate the puzzle pieces and matching holes on the pieces and core for the magnets. The core and all pieces were printed at the UoB and then post-processing was done by the author of this thesis. Finally, the puzzle-pot was painted by the artist of the RPM in order to look as close as possible to the original urn. Budget from the School of CEM of the UoB enabled the production of all assets for the case study.

When it comes to the choice of the fabrication technology to create the puzzle-pot, it was considered how this could compare to more "traditional" methods of replication. For instance, a similar puzzle could have been made by modelling a pot from a hard-wearing clay, firing and glazing it. This pot could then be smashed, reassembled and a core could be made (even though producing a core should be a rather demanding task). The whole process would not be very expensive and would require access to clay and a kiln. However, the puzzle pieces would not be fragmented in a controlled manner. For instance, the pieces would not necessarily break with the required dimensions required, the magnets would be difficult to fit and attach neatly. Moreover, if a single piece disappeared from the gallery, the process to replace it would be costly and complex. Alternatively, it would be possible to make a pot using clay and produce a mould or negative using plaster of Paris or silicone. Tin would then be used to make the shard shapes in the mould. The puzzle pieces and core would then be casted in jesmonite. Holes for the magnets would have to be drilled in the casted material. Although this process would be slightly more expensive than the previous one, it would be possible to replace a puzzle piece if this was lost (still more complex than 3D printing it with holes in place). However, the pieces could still brake (potentially harming visitors), the mould would require to be carefully guarded so it would not get lost, and it would suffer of inevitable wear. The latter issue would affect the reproduction of subsequent copies of puzzle pieces. Thus, the deployed approach presented a series of advantages in comparison to more "traditional" approaches as: it uses an authentic artefact of the collection without risking its safety (by generating a mould); it allows for simpler and more cost-effective replication of pieces (in fact duplicate pieces were given to the museum along with the digital files for easy replication); and enables the generation of puzzle pieces in desired dimensions and materials in a cost-effective way.

7.3.6 Overall study set up, preparations and processes

As done in the previous chapters, a summary of the preparations and set-up for the case study is presented below:

- **Ideation and concept development:** Valuable input for this case study came from the literature review, discussion with museum professionals, researchers and all involved stakeholders. Input from audiences during museum events, where replicas

were available to handle, has also been very useful in order to form initial concepts about the artefact, audience and character of replica.

- **Resources:** In the initial stages, the available resources for the case study were also considered. These included: digitisation equipment (3D scanner, turntable, black gazebo, camera, light tent, tripods, lights, light stands); software; technical support (digitisation lab, 3D printing suite); digital fabrication machinery (e.g. available 3D printers and their features); necessary work for the functional aspect of the puzzle (magnets, plastering, core), its installation (work from the RPM designer and carpenters) and the artistic work; camera and audio recorders for the evaluation sessions; available budget; and access to museum and audiences.
- **Museum/collection/artefact selection:** The development of the case study coincided with the installation of the new Archaeology Gallery in the BMAG. Through a series of discussions between the researcher, UoB colleagues, archaeology curators and the designer of the BMAG, it was decided to design a digitally fabricated 3D printed puzzle of an Iron Age funerary urn. More replicas were also incorporated in the gallery to enhance artefact interpretation.
- **Audience selection:** Families with children between the age of six (6) and twelve (12) years old were chosen as the target audience. Children are amongst the most popular visitors in museums as part of a school or family group. The BMAG receives a large number of families in its premises every year, while the new Archaeology Gallery targets young visitors as its priority audience.
- **Replica development:** Information about the shape of the pot was acquired through 3D scanning, using an *AICON Breuckmann 3D SmartScan* structure light scanner, whereas texture information was acquired by photography. Data were processed in suitable 3D graphics software to generate an internal core and the external 3D model that would be fractured in order to create the puzzle pieces. All these were 3D printed (the core in four pieces that were later pasted together) and then post-processed to create a functional 3D puzzle (by inserting magnets, covering the wholes etc). Artistic work was also performed to produce a 3D puzzle replica that would look as close as possible to the original urn.
- **Evaluation:** Chapter 3 analyses the overall methodology and methods for evaluation. Similarly to the other case studies, information sheets, consent forms,

questionnaires, observation sheets and activity cards (graffiti wall cards) were printed to facilitate data collection. Apart from the printed forms, the equipment/resources used for the evaluation included: the replica puzzle pot, (this is installed within the exhibition), clay shards for children to decorate, crayons, camera and audio recorders. All participating families were observed while freely assembling the puzzle and notes were kept on the observation sheet. Right afterwards, they were approached and informed about the research and asked whether they wanted to contribute to it. When participants agreed and signed consent forms, their observation data were kept, and adults were asked to fill in the questionnaire and respond to the interview questions about their experience with the puzzle pot. During that time, the children were given the clay shards and they were asked to decorate them with crayons and then write on the card what makes them special. Once finished, the shards and card were photographed, and then given to children to take home. Data from the families who did not agree to take part in the research were discarded and hence not deployed for the research. The data that were used for the research were later transcribed to facilitate data analysis.

- **Pilot study and data collection:** The pilot study took place at the BMAG with a participating family. The puzzle pot was located within the Iron Age section of the exhibition and the researcher had to stay right outside of this area in order to have visual access when observing families assembling the puzzle. Interviews, questionnaire completion and craft activity took place in the educational area of the Gallery (at the centre of the exhibition). During the pilot and further data collection on that day, it was noticed that people would be more willing to try the activity when the puzzle was unassembled. Hence, the researcher would often disassemble the puzzle and put pieces around the core. As explained before, this was a conscious act related to the experiential setup during evaluation. Some of the difficulties encountered on the pilot day were related to heavy visitor flows, which impeded the collection of data and hence the researcher had to stop and wait for the space to become less crowded. It was also noticed that larger families were more reluctant to participate, as it was difficult to control many children while providing feedback. Therefore, smaller groups were prioritised. As far as it concerns younger children who wanted to try the craft activity, these were not excluded, and they were given a

shard to decorate but their data were not included in the research. Lastly, evaluation materials (shards, crayons, questionnaire sheets, participation forms) had to be better hidden/protected to prevent visitors from taking them away. Further data collection sessions took place in BMAG the following days/weeks.

- Data processing and analysis: Quantitative and qualitative data were transcribed and analysed as described in 3.4.11.

7.4 Evaluation

The puzzle, its design and performance were initially tested with the design team and the curators of the RPM. Testing has been an iterative process throughout the digital fabrication workflow to see whether functional (behaviours) and non-functional (overall qualities) requirements of the activity had been met. The feedback from this process informed design decisions at subsequent steps of the workflow. Next, the evaluation of the activity and its performance with families took place once the Archaeology Gallery was open and full Tier 2 approval had been granted by the *Life, Health and Physical Sciences Cross-School Research Ethics Committee* (CREC) of the UoB.

7.4.1 Data collection methods

The data collection methods that were deployed were both of quantitative and qualitative nature as in the previous case studies and in accordance with the RXF theoretical proposition (see Chapter 4). Therefore, the data collection methods were:

- semi-structured observation notes;
- short questionnaires;
- semi-structured interviews;
- artefacts and graffiti wall cards.

A copy of the observation protocol, a sample of a transcribed observation, the questionnaire sheet, the interview sheet along with a sample of a transcribed interview, and a sample of a card to collect feedback from children for the third case study can be found in Appendix D.

7.4.2 Pilot study

The pilot study took place at the new Archaeology Gallery of the BMAG in May 2019 on a half-term day, when families with children of the target age were expected to visit the museum. All the practices related to data collection were initially tested with a family that agreed to

participate in the trial. More visiting families also contributed to the research on that day and some valuable remarks were made mostly with respect to time management and visitor flows in the gallery.

As stated before, the interactive puzzle-pot is placed in the Iron Age area. The puzzle-pot is located at a corner, right next to a display showing a video about weaving practices in the Iron Age (fig. 78 left). The original urn can be found in a display along with other artefacts opposite and diagonally from the puzzle exhibit.

Figure 78: The puzzle-pot unassembled at the corner of the Iron Age area (left) and family testing the activity (right).

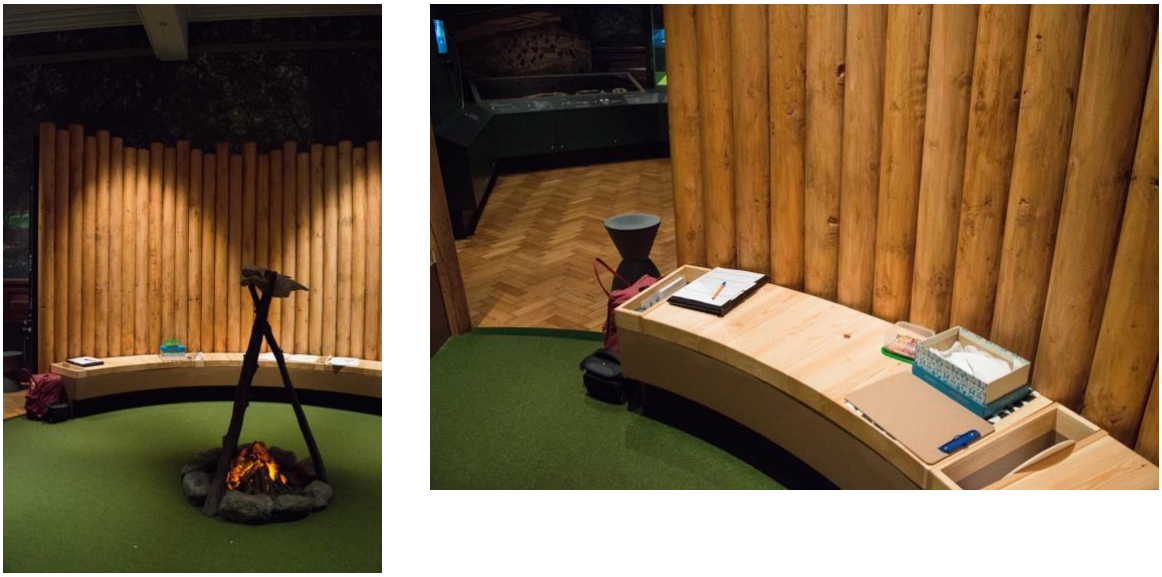


Figure 79: The educational area in the centre of the Gallery where interviews and craft activity took place (left) and close up of the research materials on the spot (left).

In order to observe and keep notes about the participants interacting with the puzzle-pot, the researcher had to stand right outside of the Iron Age area, as this was the only point with visual access to the spot. When visitors had finished with the puzzle-pot, they were invited to come to the central area of the gallery which has been designed to host educational activities and hence has some more space (fig. 79). There, visitors (both adults and children) would be informed about the research and, upon agreeing to participate and signing all related consent forms, the adults were handed a single-page double sided questionnaire to fill in. While adults were filling in the questionnaire, the children were given a small puzzle piece made of clay and they were asked to decorate it the way they wanted with crayons. The children were also given a card with a printed frame where they could place their decorated artefact in the end and write what makes their puzzle piece special (fig. 80). In the meantime, most adults had finished with the questionnaire and could proceed to the interview. All interviews were audio recorded and later transcribed to analyse the data.

Figure 80: Children participating in the craft activity with adult sitting with them.

When children had finished with the craft activity, the researcher would ask them about their artefact and the idea they had written on the card and take a photo of their artefact on the card. Finally, the children would be given their artefact and card to take home.

7.4.2.1 Lessons learned

The pilot study day has been very useful not only in terms of providing data, but also to trial the best strategies to handle visitors' flows and organise the activities related to the study.

In the first instance, is was decided to observe visitors assembling the puzzle from a distance, as the Iron Age area is already limited and moving very close to visitors could be considered intrusive. Hence, the researcher was standing between the Bronze Age and the Iron Age area. This was the only place providing visual access to the puzzle spot. When families, and especially those with many members, stood beside the puzzle spot they often occluded that corner and made observation difficult. This also meant that part of the auditive information between members of a group could be also lost, due to noise (when the gallery was busy) or simultaneous talk or talk at a very low volume.

In addition, it was noticed that when the gallery was crowded it was difficult to perform the data collection, due to constant movement of visitors (that obstructed observations) or limited availability of space. Occasionally large groups of people (e.g. school children visiting

from abroad) would occupy the interview area and there would not be room to allow visitors to sit and take part in the research. Hence, the researcher had to stop and wait for these groups to leave before continuing the data collection. Lastly, large family and friend groups proved more difficult to handle and people would be reluctant to participate in the research when they had children running around the room or being occupied in different activities at a time. In such cases, adults had to be vigilant and could not sit for the interviews. Another concern for the researcher was looking after the data collection materials, while observing visitors assembling the puzzle. As the central area of the gallery had also other available resources to interact with, some children and adults would try to look into and even take the data collection materials. A measure, that proved to prevent people from removing materials, was to place a note kindly asking visitors not to open the boxes.

With respect to getting approval from the participants, it was decided to hand more than one consent forms when numerous families came as one group. In such case, an adult would participate in the research and more than one child could take part in the craft activity. Therefore, guardians would be asked to separately give their consent (apart from the children's consent forms that would be signed by themselves anyway). In other cases, it was noticed that younger siblings wanted to try the crafting activity too. These children were not excluded but were rather given a clay piece to decorate and play with. However, their data were not included in the research.

Lastly, as a number of unstructured non-formal observations had already taken place in the museum even before the pilot day (to prepare for data collection), the researcher noticed that visitors were reluctant to try the activity when the puzzle was already assembled. This also became obvious on the pilot day. For this reason, the researcher would often disassemble the puzzle and put pieces around it when people had finished with it. This was a conscious act rather related to the experiential setup and without any intention to alter data. After all, feedback will be provided by the researcher to the RPM officers about the evaluation the activity, in order to improve it if possible.

7.4.3 Further collection of data

After the pilot day, more data were collected in June 2019 at weekends in order to be able to access families with school age children. Data collection took place both in the morning and

in the afternoon. Even though there was an effort to balance sampling, as for men and women adult participants, women are overrepresented in the study.

7.5 Findings

The following sections present the analysis of data from twenty-six (26) families with children between the age of six (6) and twelve (12) years old who participated in the research. The analysis, as in the previous case studies, starts with the description of contextual information (personal, social, physical data). Then, the expression - perception of the experience of the puzzle-pot is examined in terms of awareness/knowledge, engagement/interest and so on, as presented in the RXF concept (Chapter 4).

7.5.1 Personal context

Twenty-six (26) families with children between the age of six and twelve took part in the research. All families were observed while interacting with the 3D puzzle-pot and were then invited to the centre of the gallery to fill in a questionnaire and respond to the semi-structured interview questions. While adults were responding, the children were taking part in the craft activity, as explained in 7.4.2. Amongst the adults that participated, seventeen (17) were women and nine (9) were men (fig. 81). Even though the researcher put an effort to include more male participants and hence balance sample better, it was noticed that women were often more willing to take part in the research or men preferred to give their place to women and invigilate children. In many cases, though, families comprised mostly female adults with children. As for the twenty-nine (29) children that took part, eighteen were boys (18) and eleven were (11) girls with ages ranging from six to eleven years old.

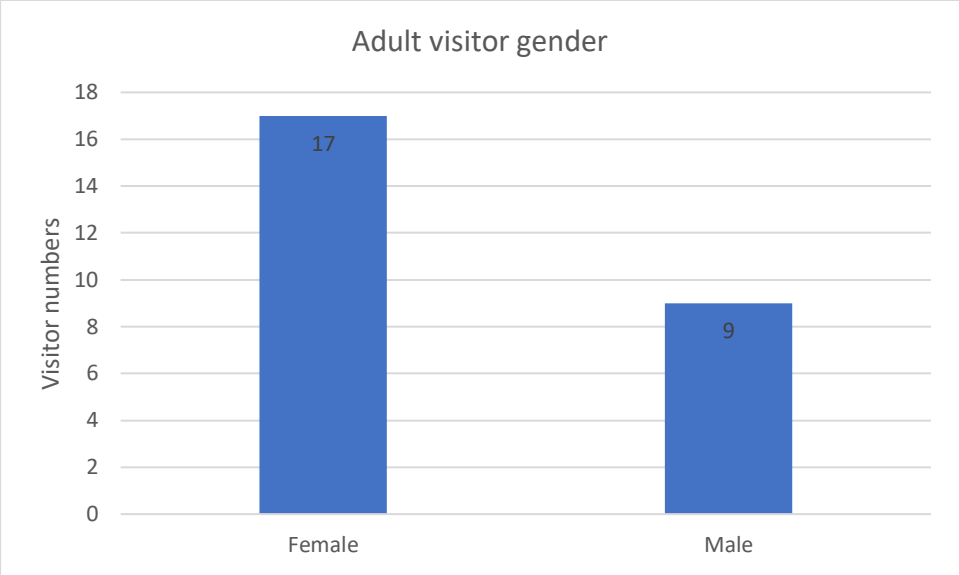


Figure 81: Female and male adult visitors, members of a family group, participating in the study.

Adult participants' age is presented in fig. 82. Most participants belong to the groups of 25-39 and 40-49 years old. This can be explained by the fact that the majority of participants identified themselves as parents of the children and these ages agree with national statistical data showing that people between the ages of 25-29 and 30-34 years are the ones giving most births (hence have children of the target group age 6-12 years later) (Office for National Statistics, 2011). Fewer participants belonged to ages above 50 years and these were mostly grandparents of the children. Younger adults between the ages of 18-24 are not present in the sample and this can also be justified by the above statistical data. Further data of demographic nature, such as ethnic background and distance of residence from the museum were not collected. As the study involved children, these data were considered sensitive by the CREC of the UoB and hence were omitted.

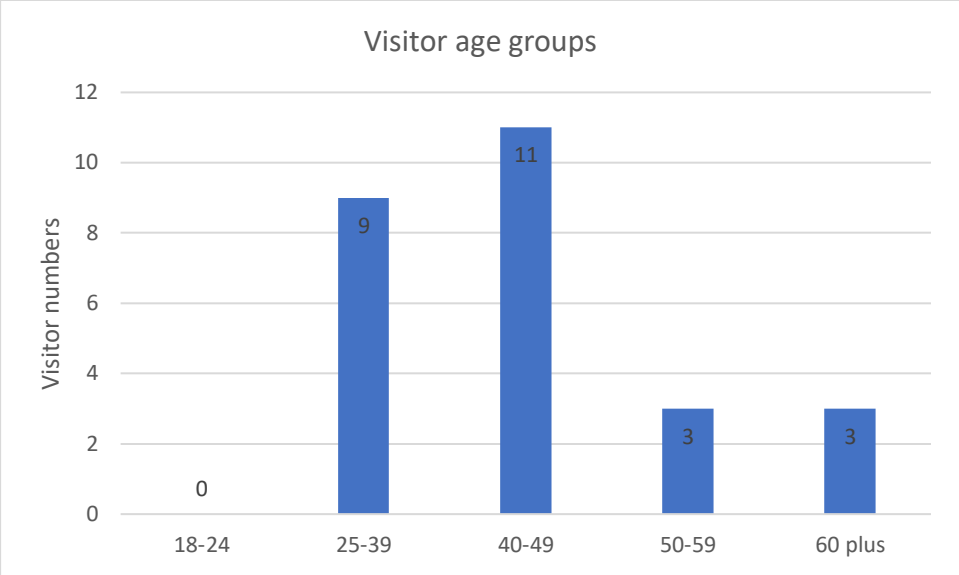


Figure 82: Adult visitors' age groups.

With respect to visitors' past experiences, people were asked whether they had visited other museums in the past and whether they had visited the Brighton Museum before. The vast majority (24 participants) had visited other museums and galleries before (fig. 83). Only two (2) participants had not visited other museums, however they had visited the BMAG before. In total, for twenty-one (21) families this was a repeat visit to the museum, whereas five (5) families were visiting this museum for the first time.

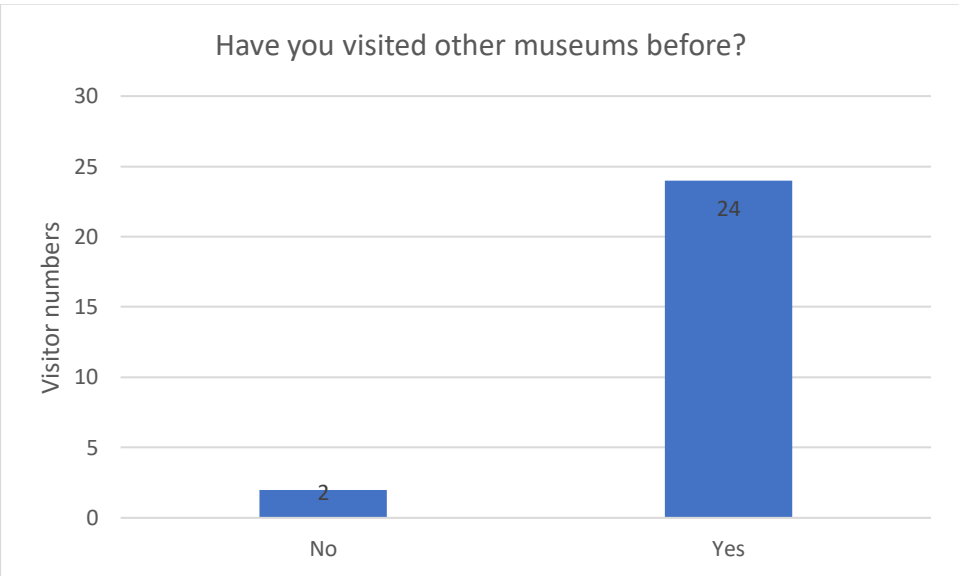


Figure 83: Previous visits to museums.

When asked about their past or current occupation, twenty-three (23) participants stated that it was not related to cultural heritage, but three (3) said that it was. These were people working in education settings and in performance arts.

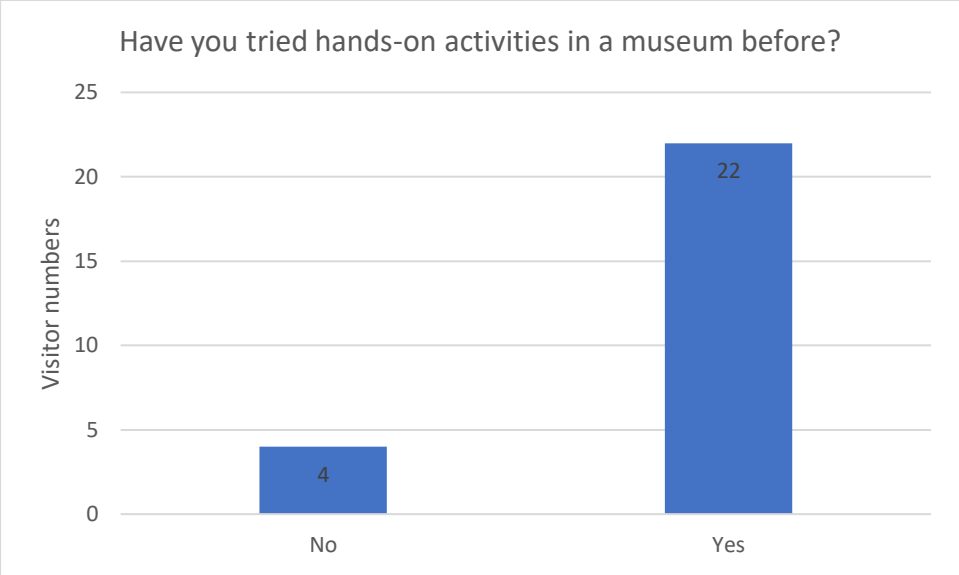


Figure 84: Previous experience in using hands-on activities in museums.

Further data about past experiences with hands-on activities in museums reveal that twenty-two (22) families had tried such type of activities in museums, whereas four (4) had not (fig. 84). Through the analysis of data, there does not seem to be any pattern relating past museum visits or age group classification to previous hands-on activities. As for having the opportunity to touch museum objects in the past, the majority of participants had been "rarely" provided with museum objects to touch, while ten (10) had sometimes. Two (2) participants, had never touched museum objects and only one (1) with a background related to CH had often touched them before (fig. 85).

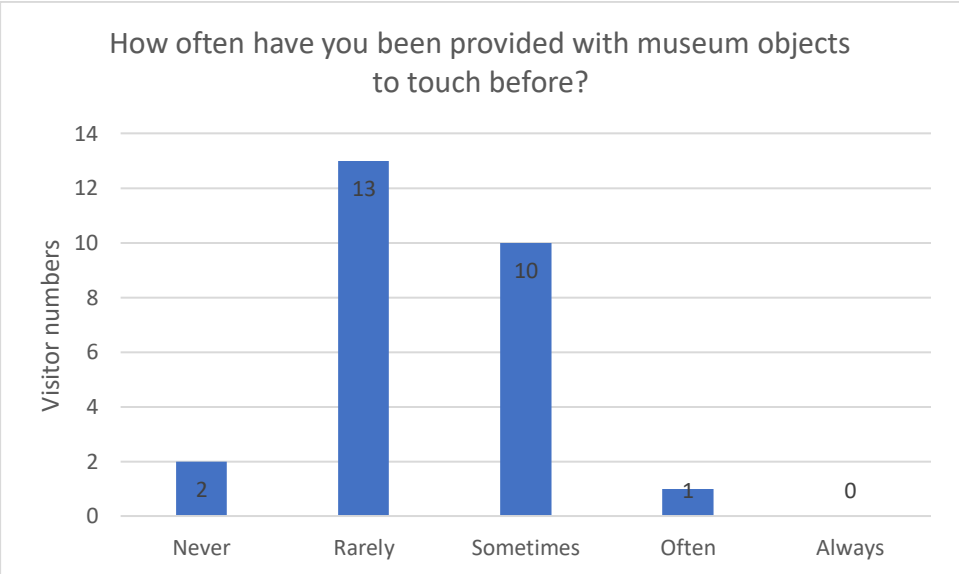


Figure 85: Previous experience in touching museum objects.

With regards to people's expectations and interests, the research sought to investigate what were people expecting to do at the museum while visiting and what were the things that would interest them the most. As table 26 demonstrates, most families (10 participants) came to the museum expecting to explore a specific collection or exhibition; with the Archaeology Gallery being the most popular one, followed by the Wildlife Photographer of the Year exhibition (loan from the Natural History Museum, London) and the Egyptology collection. Another part of visitors came to the museum with the intention of enhancing learning especially for the children (5 participants), while other families came to do a general exploration (4 participants) or did not have any particular expectation (5 participants). Two (2) participants did not say whether they had any expectations. Particularly interesting were some parents'/carers' comments when stating their expectations, evidencing the desire to find interactive hands-on activities and/or touching objects to better engage children with CH related explorations:

"Explore Brighton's history and culture with the hope of interactive activities to do there."

"Expected to look around and read. It was a nice surprise to find activities more engaging for the family."

"I liked this exhibition a lot! Being able to bring to life the past through 3d images, video and objects made it very special and learning was easier."

Expectations (tendencies)	Participants	Representative people's comments
Explore a specific collection or exhibition (e.g. Egyptology, local archaeology, wildlife photography)	10	*"To explore the wildlife photography exhibition."* *"Grandmother interested in archaeology and grandson interested in Egyptian section and puppets."* *"I wanted to come and see this exhibition."*
Learn and be inspired and find out information	5	*"Enhance children's learning and interest into history and arts. Interested to see the Egyptian and Stone Age sites."* *"My son watches a lot of horrible histories, so is quite knowledgeable already, but I hoped to reinforce what he's learned and add a bit to it (e.g. Iron Age people and their life)."*
Explore collections/general visit	4	*"A wide variety of expositions, such as pictures."* *"Spend an hour looking at interesting stuff with our kids."*
Nothing in particular (no expectation)	5	*"Didn't have any expectations, we came because it was raining."*

Expectations (tendencies)	Participants	Representative people's comments
		"No idea!"
Did not say	2	

Table 26: Tendencies in participants' expectations.

Lastly, as far as it concerns participants' interests, thirteen (13) participants mentioned that they were interested in specific collections (table 27). Their comments agree with expectation data, as the local history/archaeology topic and the new gallery were mentioned the most.

Interest	Participants
General collection	4
Specific collections	13
No specific interest	3
Royal Pavilion	1
Other topic (not currently covered by the museum)	1
Did not say	4

Table 27: Tendencies in participants' interests.

Furthermore, four (4) participants were interested generally in the collections, while three (3) had no specific interest. Some participants preferred not to share their interests (4 people), while two (2) were interested in the Royal Pavilion and topics that are not covered by this museum (science).

7.5.2 Social context

The social context of the experience is related to the composition of each visit, the social environment in the exhibition area as well as the interactions within a group or between groups of visitors. The target group of this case study were families; hence all participants came to the museum as members of a family group. According to recent research, 35% of museum audiences are family groups (The Audience Agency, 2018). The BMAG also receives a considerable number of visitors coming as family groups (Royal Pavilion & Museums, 2018; Thomas et al., 2016). The participating families had from two to five members and usually comprised parents, grandparents, children and in some cases adult or children friends. As for the social environment of the gallery and particularly the Iron Age area, it was observed that,

when that space was occupied by other visitors looking at the artefacts, watching the weaving video or assembling the puzzle, people were reluctant to enter it. The whole gallery is dimly lit, and the puzzle-pot is placed at an occluded corner, thus spotting the activity was not always easy. When the environment was not crowded and there was a comfortable visitor flow, people would enter the area and -if not distracted by the video- would assemble the puzzle.

Observational data demonstrate that both physical and verbal interactions took place while assembling the puzzle. The first ones included: physically motivating the child to go to the area of the puzzle and try the activity (by adult, sibling or friend); physically collaborating to assemble the puzzle, by rotating the core, handing pieces to each other or placing them and pointing at marks/clues on the core; pushing each other, as in two cases children of the same group tried to grab the pieces and put them on the core first[47]; lifting a younger sibling who wanted to reach and participate in the assembly; looking to see where the other family members are to demonstrate the successful assembly; clapping or smiling or laughing with joy when placing the pieces correctly and completing the activity. In nine (9) cases, a child assembled the puzzle alone, whereas in five (5) cases two children collaborated to assemble the puzzle together. In twelve cases (12) both adults and child or children worked as a group. Even when a child/children assembled the puzzle alone, most adults would have some verbal interaction with them during the process.

Apart from physical interactions within one group, though, further interactions between groups were noticed. Therefore, in some cases families would see other people assembling the pot, they would become interested and they would wait to try it themselves. This behaviour has been analysed in visitor research with a variety of terms, such as “social influence”, “modelling behaviour”, “mutual monitoring”, all focusing on behaviours that are socially influenced during the visit (Falk and Dierking, 2013, p. 154; Vom Lehn et al., 2005).

Verbal interactions are particularly rich and cover the whole timeline of the puzzle-pot assembly. In the first instance, a number of quotes is related to motivation to try the puzzle

[47] A sense of competition was also mentioned (in a positive way) by an adult who said that both her and her daughter wanted to find the next piece as fast as they could to put it on the core and complete the puzzle first. In three more cases, children asked parents to let them do the puzzle alone as they got excited by the activity.

activity (*"Try to do it on your own!", "Can you make the broken pot?" "Let's try to make a pot"*). Then, a number of quotes refers to guidance and verbal help before or when executing the activity (*"Let's put the top pieces on the side", "You have to find the shape that fits", "Look at the pattern", "Shall I give you a clue? You have to find shapes"*). Such guidance in most cases came from adults, but less often it came from siblings or friends. A large part of the verbal reactions is dedicated to corroborating findings or praising a child when a piece is placed correctly *("Aren't you clever?", "That's it! Well done!"*) or celebrating the successful completion of the puzzle in the end *("We have made a pot! Yeah!", "Fabulous, I am very impressed!", "I like it! I did it!"*). Lastly, only a small number of comments refers to the original pot as there were not many families associating the puzzle-pot to the original urn placed in the opposite display (*"We need to make it to look like that", "What does it say about this pot? It doesn't say anything"*) (see following section).

7.5.3 Physical context

The examination of the physical context of the experience, as shown in the RXF (section 4.3), refers to the original artefact, the physical exhibition setting and the interpretative material which supports the exhibit including the replica and its performance. The information about the original pot and its possible production, type and function has been presented in 7.3.2.

When it comes to the exhibition setting and activity location, it has been mentioned that the original urn and puzzle-pot activity can be found in the Iron Age dedicated space within the Elaine Evans Archaeology Gallery along with other artefacts, human remains, facial reconstructions and other interpretative means. The puzzle-pot is placed in a cove almost at the right bottom part of the Iron Age area and at a medium height. Behind the puzzle, the wall is decorated with a print of an enlarged photo of the original urn (fig. 79). In front of the puzzle there is a small tray where the puzzle pieces can be left. This was a later addition, as pieces used to fall down very often (and sometimes got damaged) due to the lack of space to lay them around the core. However, the added tray covered a printed label inviting visitors to assemble the pot (fig. 77 bottom right and fig. 78). As the Iron Age space is quite narrow, the puzzle-pot can be missed unless visitors enter this specific section and spot the puzzle. Moreover, the activity can be easily hidden when the gallery is busy and/or other visitors are in the Iron Age corner. The original pot along with the bones it contained is placed in a display opposite the puzzle-pot without any further interpretative information. The gallery in general

has dim lights and the atmosphere is mostly dominated by the human remains, facial reconstructions and the images and sounds coming from the screens playing videos about daily human activities (fire making, metal making, weaving etc).

When families spotted the puzzle-pot activity they were generally attracted by it. Yet attraction to the activity was heavily affected by four factors: a. the location of the activity as it is almost hidden, and in many cases people cannot see it *("I would prefer the puzzle to be in a more visible/accessible position", "It is a bit hidden and it is easy to miss", "It was too isolated and tucked away", "More accessible, not in the corner", "I think it's a bit of a shame that it's right in the corner of the exhibition so it's a bit tricky to get to"*); b. the narrow space which makes some visitors to avoid the Iron Age section when the gallery is busy; c. the screen with the video right beside the puzzle-pot that often disrupted visitors from paying attention to the puzzle *("It is quite an intense little corner over there with the video and the puzzle-pot", "Video right next to it was distracting us a bit from the puzzle activity")*; d. the lack of information to explain the activity or invite visitors to try it (covered by the addition of the tray). Such remarks can be further supported by unstructured observations of families in the gallery. Thus, it was noticed that most children when entering the gallery would immediately seek for any available hands-on activity. Other activities, that are placed right in the centre of the gallery, can be immediately seen (foam skeleton assembly and roman arch assembly). These were very popular amongst younger audiences and children would wait for another child to finish in order to try the activity next.

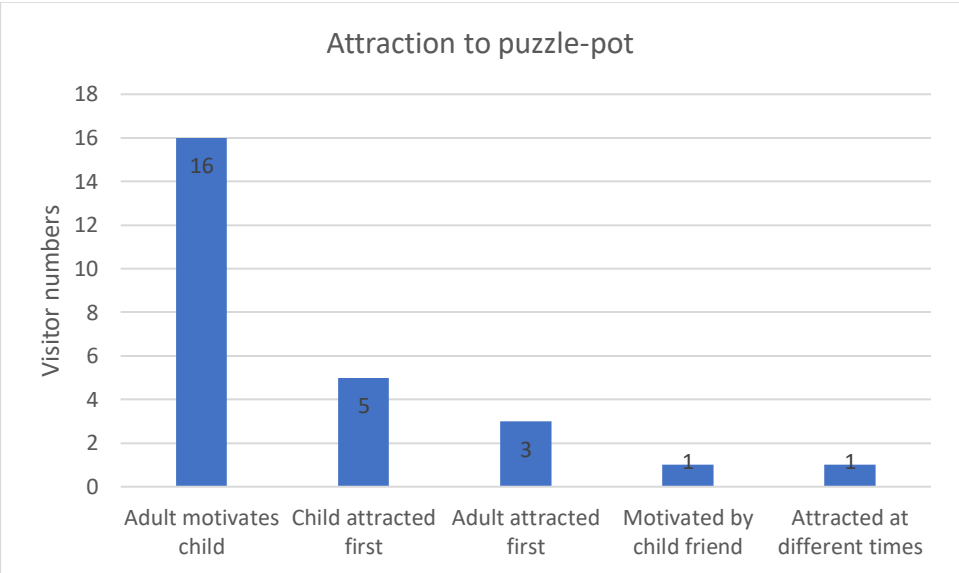


Figure 86: Visitor attraction to the puzzle-pot activity.

In the puzzle-pot case, adults often spotted the activity first and then took/motivated the children to try it; something that could be related to their role as "facilitators" or "mediators" of "personal and collective agendas" within the family (Falk and Dierking, 2013, pp. 153–154). Hence, in sixteen (16) cases the adults spotted the activity and motivated the children to interact with it. Five (5) children spotted the activity first and started assembling the pot, with adults following them. Three (3) adults started assembling the pot by themselves and children saw them and joined in. In one (1) case a friend took the child to the activity and there was also a case (1) of an adult and a child from the same family group spotting and assembling the puzzle at different times.

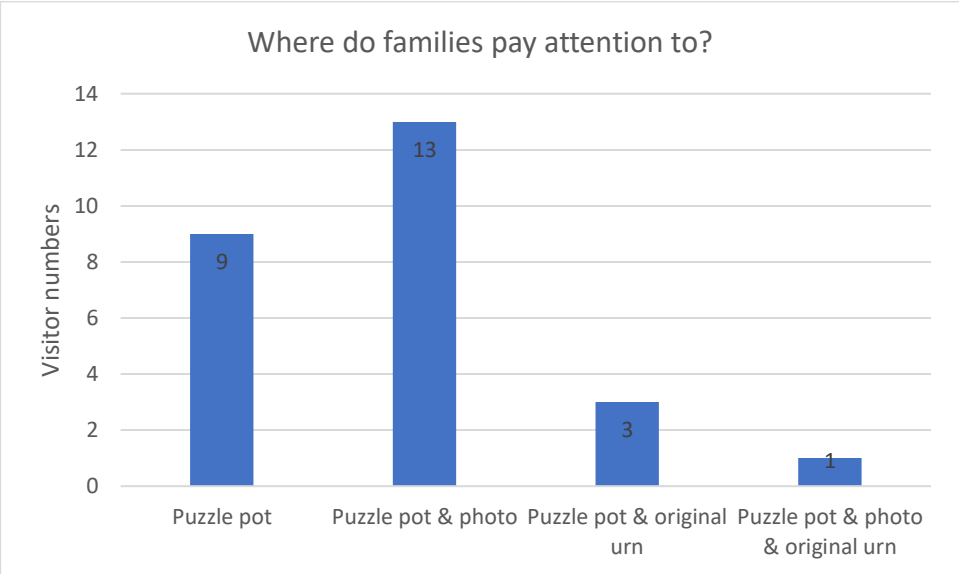


Figure 87: Visitor attraction to interpretative means.

More data related to families' response to the artefacts and interpretative means reveal that most visitors (13 families) paid attention to the puzzle-pot activity and the printed photo behind the puzzle-pot (fig. 87). However, when asked, eight (8) families amongst them admitted that they looked at the photo after or that it did not help them for the assembly. Nine (9) families paid attention only to the puzzle-pot. Three (3) noticed the puzzle and the original urn and only one (1) family paid attention to the urn and all interpretative media. Amongst the four (4) families that paid attention to the original urn, one (1) could not understand if the puzzle-pot replicates the urn *("What does it say about this pot? It doesn't say anything", "It was the pot from here, wasn't it?")*; one (1) family noticed the urn, but when later asked they said they did not relate it to the puzzle; and two (2) families clearly related the puzzle to the original urn. Such data demonstrate that, even though the puzzle activity

managed to engage families, only a very limited number amongst visitors managed to relate it to the original artefact. Thus, there seems to exist a certain lack of contextuality due to the lack or further written information and location of the activity (see 7.5.4.6 on contextuality).

As far as it pertains the sense of usability for the activity, observational data show that families were able to complete the activity with effectiveness and there has not been any case of people quitting the puzzle. Most families were able to complete the activity in less than one minute and up to three minutes (apart from limited cases that they assembled the puzzle more than once)[48]. In thirteen (13) cases a child or children assembled the puzzle by themselves, whereas in nine (9) cases both adults and children "put their hands on it". In three (3) cases adults started and then children interrupted and asked to do the puzzle themselves and in (1) case an adult and a child assembled the puzzle at different times. When children assembled the puzzle alone, adults would corroborate findings or verbally give instructions (see 7.5.2).

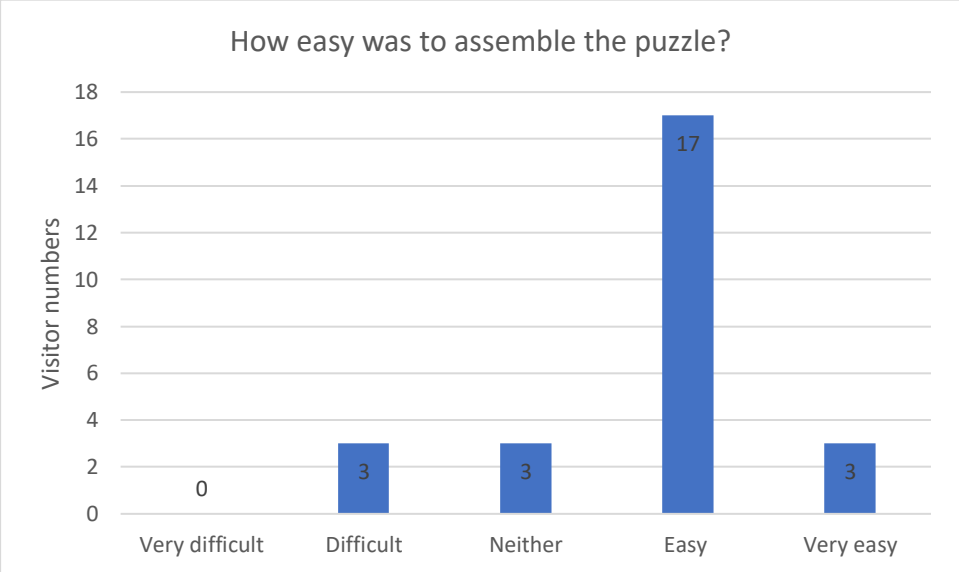


Figure 88: Ease of assembly evaluation by the participants.

When rating the ease of assembly, the majority of people (17 participants) thought that it was "easy" to assemble the puzzle (fig. 88). This can be considered a positive outcome, because families need to feel comfortable enough to complete the activity without finding it too

[48] This is a general observation that does not intend to deploy time measurement as an indication of some participants being more successful than others in performing a task/assembling the puzzle.

difficult or too easy (*"I like it because it's not immediately on… it's not too easy", " I think it was just right for a 6-year-old and for her attention", "…it was challenging enough, she didn't rush, it wasn't quickly done. It was nice she really had to think about it, which is nice"*). Furthermore, some features of the puzzle, such as the magnets and the way pieces "click" on the core, as well as the lines on the core to facilitate assembly have been positively commented: *"The magnets make the work easier", "The magnets are brilliant!", "So, I think it's easy enough for them to do it, so they can do it, it is easy because they have the magnets", "I liked that it was not very easy. If we took the lines off the core it would make it more difficult"*. Only one parent mentioned removing the lines from the core as a desirable improvement that would make assembly more difficult *("I think the only thing that would improve it is if you took the lines off. Although that it makes it easier for young children, but it would make it just… extra level"*). Three (3) participants with children between the ages of six and seven found the assembly difficult, yet they were "satisfied" or "very satisfied" with it. Another parent also mentioned that initially the activity seemed more difficult and perhaps more appropriate for older children. In all cases, it was observed that the rotation of the core greatly facilitated the assembly. However, as the area is not accessible from 360 degrees and the height of the activity can be restricting for younger children, some parents had to lift younger siblings who wanted to take part. Hence, there is certainly room for a more "inclusive" design approach.

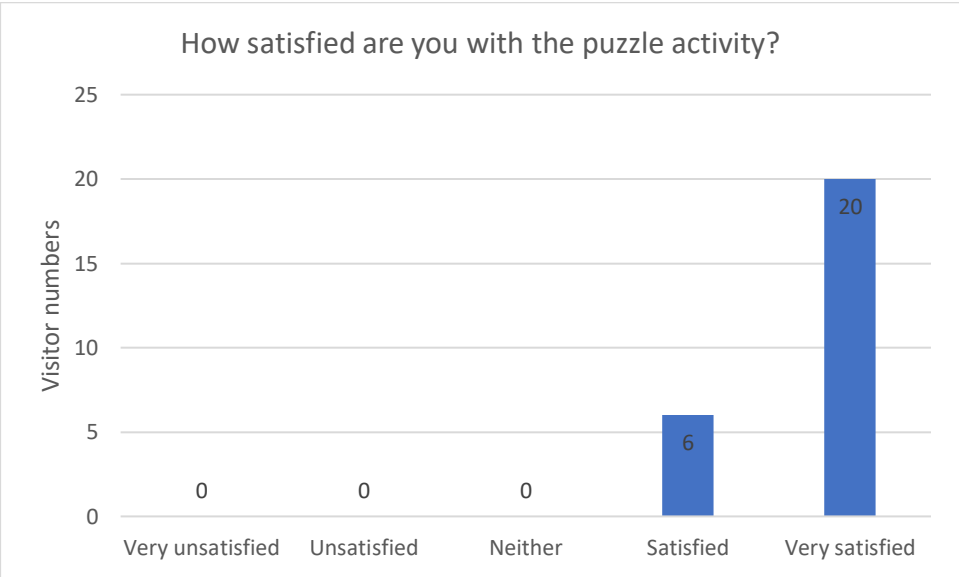


Figure 89: Overall activity evaluation.

The overall visitor satisfaction by the activity is presented in fig. 89. All participants were “satisfied” and “very satisfied” with the activity; something also reflected in comments coded under the engagement theme in 7.5.4.2.

The evaluation of the replica puzzle-pot further included rating its subjective sensorial properties on a 5-point scale. The properties that were examined reflect the visual and tactile properties’ classification as presented in the RXF (4.5.3.3). The following charts (fig. 90-99) present the quantitative data analysis of the subjective sensorial evaluation.

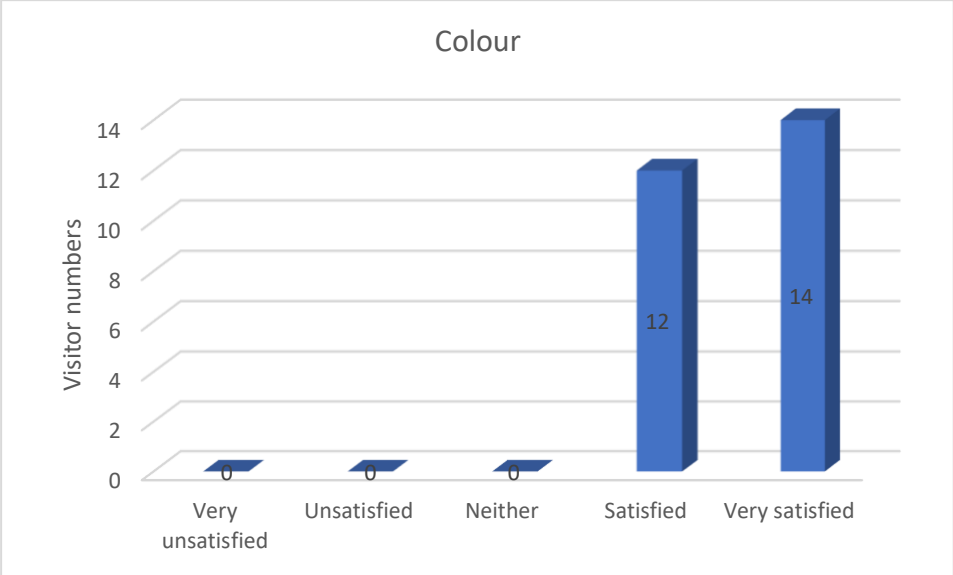


Figure 90: Rating of the subjective sensorial visual property of colour of the puzzle-pot.

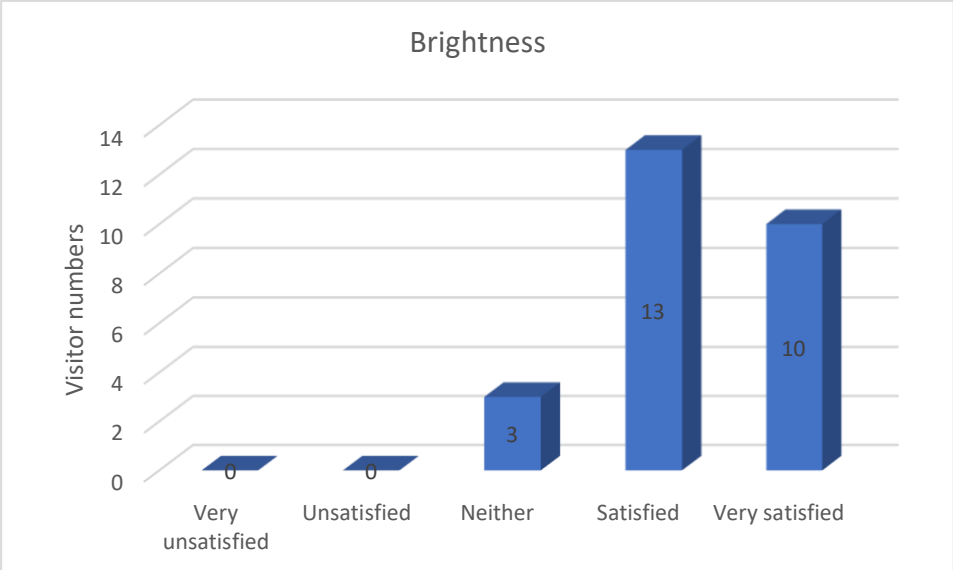


Figure 91: Rating of the subjective sensorial visual property of brightness of the puzzle-pot.

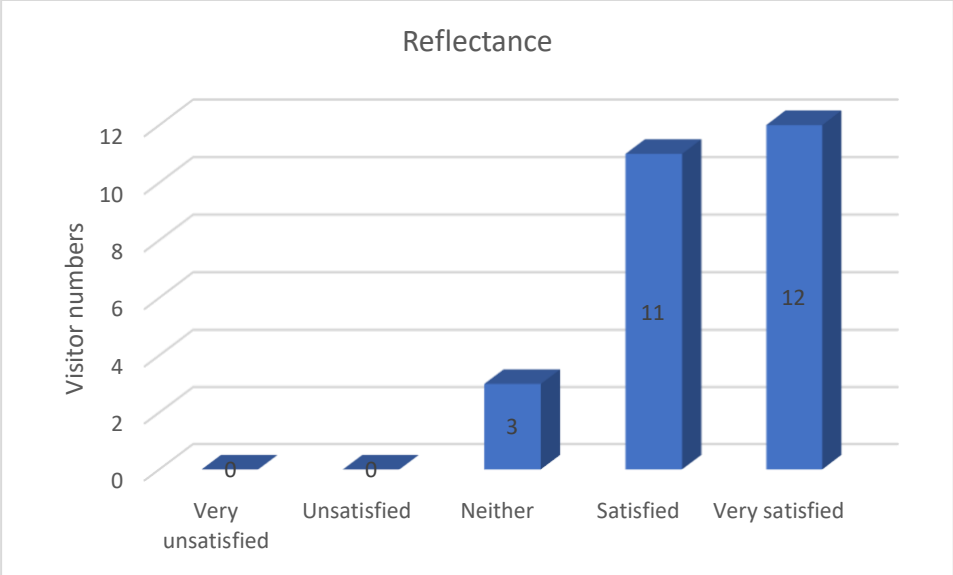


Figure 92: Rating of the subjective sensorial visual property of reflectance of the puzzle-pot.

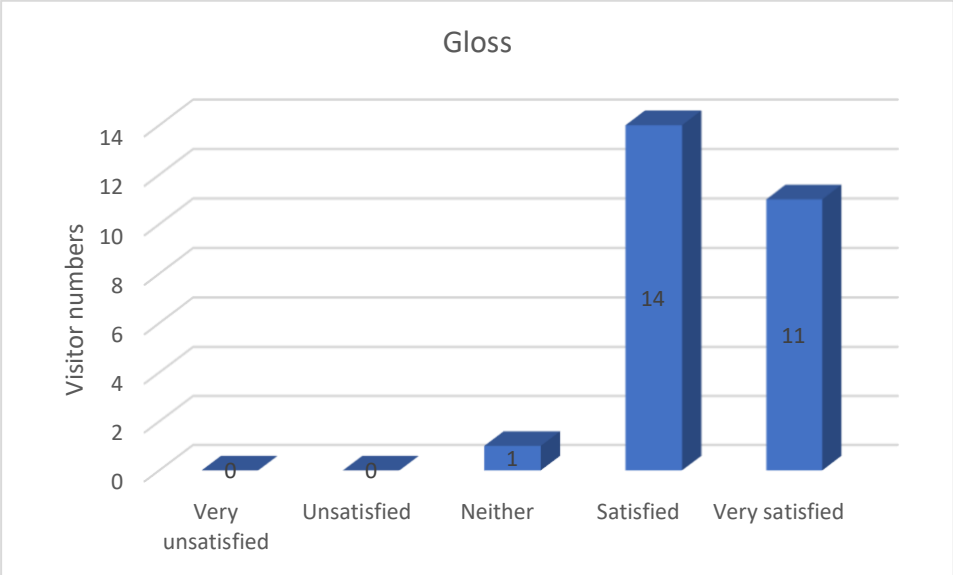


Figure 93: Rating of the subjective sensorial visual property of gloss of the puzzle-pot.

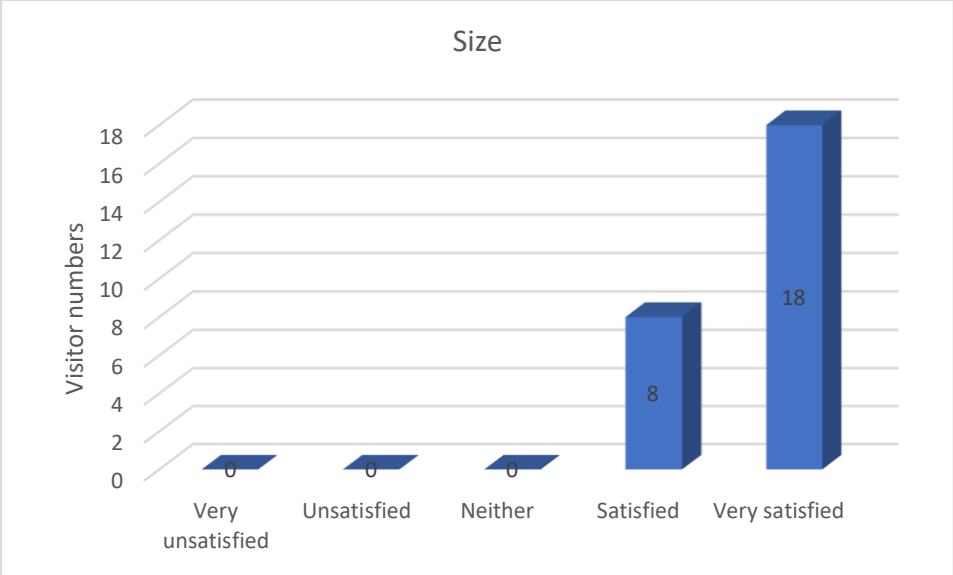


Figure 94: Rating of the subjective sensorial visual/tactile property of size of the puzzle-pot.

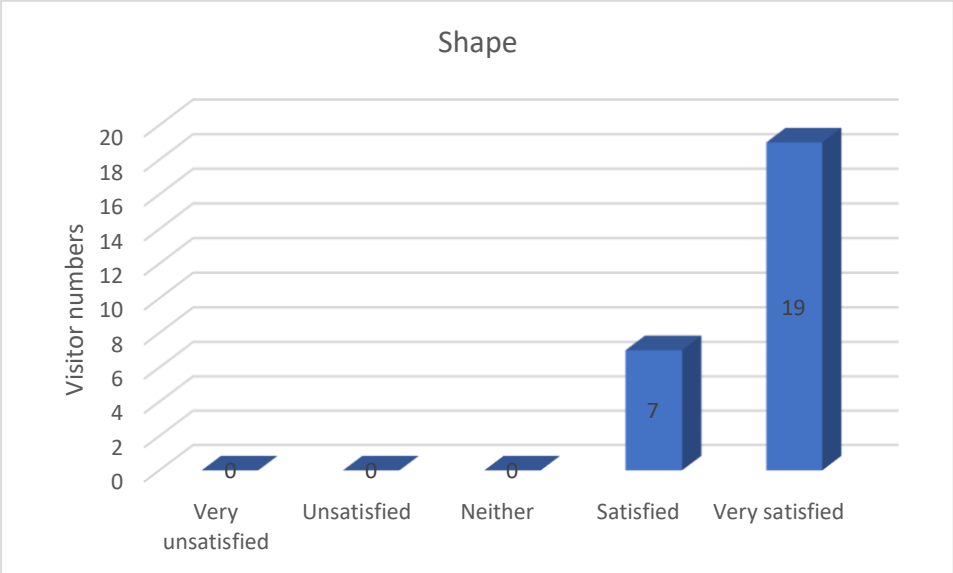


Figure 95: Rating of the subjective sensorial visual/tactile property of shape of the puzzle-pot.

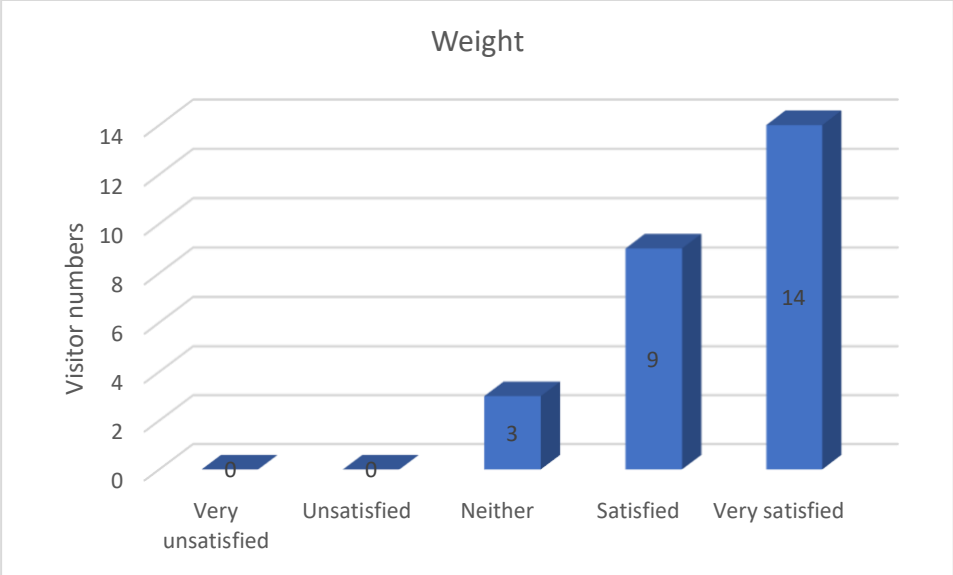


Figure 96: Rating of the subjective sensorial tactile property of weight of the puzzle-pot.

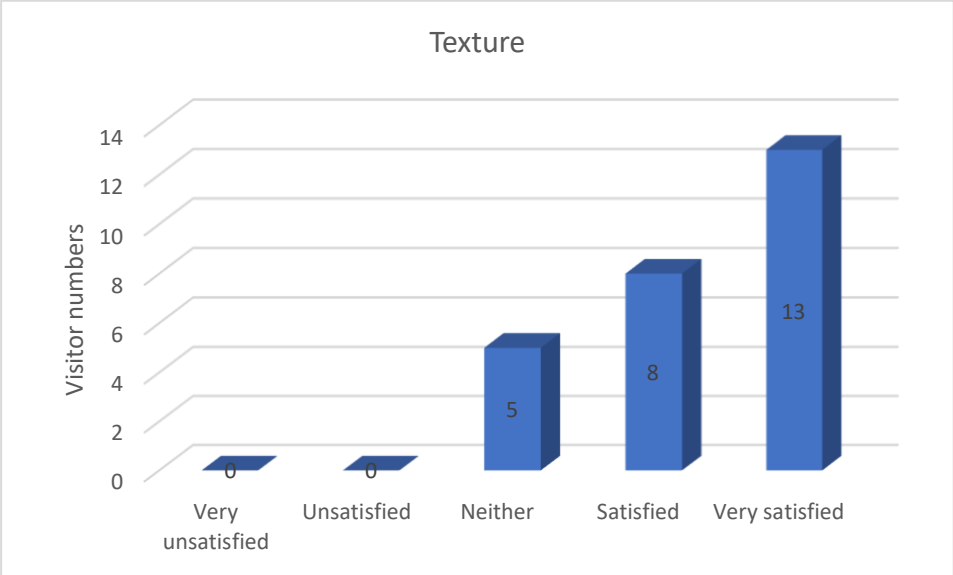


Figure 97: Rating of the subjective sensorial tactile property of texture of the puzzle-pot.

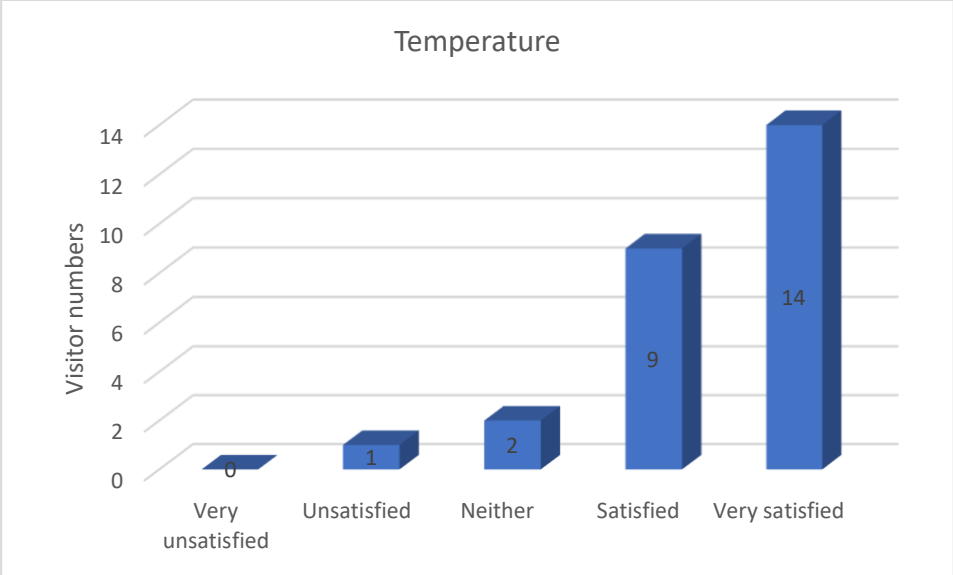


Figure 98: Rating of the subjective sensorial tactile property of temperature of the puzzle-pot.

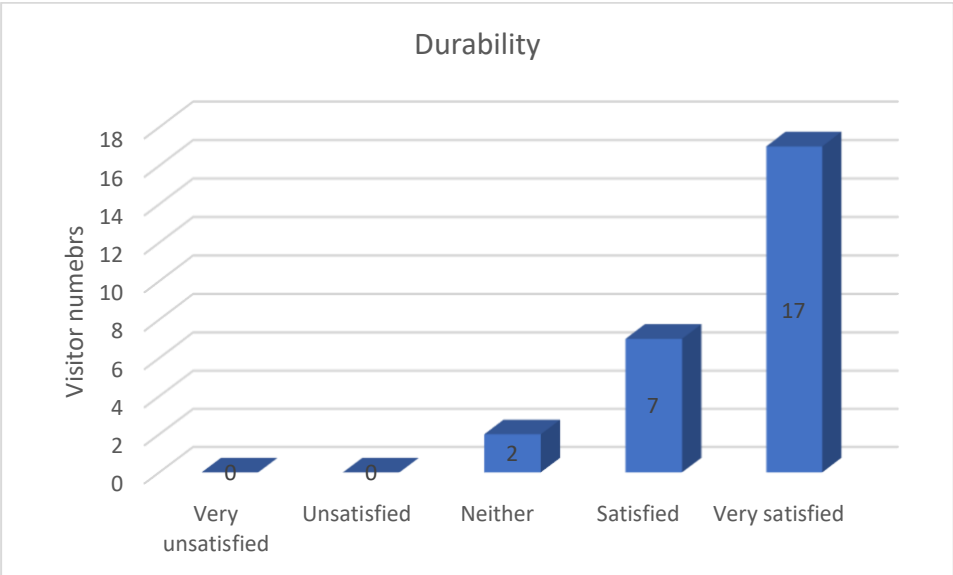


Figure 99: Rating of the subjective sensorial tactile property of durability of the puzzle-pot.

As data reveal, the overall sensorial performance of the replica pot has been very good, as the majority of participants rated its properties positively. The aim to create a replica that would be as close as possible to the original, while taking into consideration contextual parameters (e.g. target age, functionality-interactivity, available resources) might have proved a good decision and an appropriate strategy to move forward. However, it must be mentioned that these ratings might have been affected by the presence of the photo of the original behind the activity, but not particularly by the original urn as people did not relate it to the puzzle-pot in most cases.

In more detail, visual properties mostly received positive ratings with visitors being "satisfied" or "very satisfied" with them: colour got twenty-six (26) positive ratings (fig. 90); brightness twenty-three (23) (fig. 91); reflectance twenty-three (23) (fig. 92); and gloss twenty-five (25) (fig. 93). Apart from the property of colour, the rest of the visual properties also had some neutral ratings, as some visitors were "neither satisfied nor unsatisfied" with them. This might reflect a certain difficulty to rate such properties or the lack of connection -and hence comparison- to the original. There does not seem to exist any pattern with respect to these people's background, apart from the fact that they belong to the same target group and none of them connected the replica to the original pot. Qualitative comments further corroborate satisfaction from the "appearance" (visual properties) of the pot: "*It was very interesting (well painted as well)", "Looks good when completed"*.

As far as it concerns the visual/tactile properties of size and shape, all participants were "satisfied" or "very satisfied" with them and there were no neutral or negative ratings at all (fig. 94-95). The tactile property of weight got positive ratings too (23 in total), though three (3) participants were "neither satisfied nor unsatisfied" with it (fig. 96). One of them later mentioned that would want the pieces to feel heavier. The same comment came from another participant who stated that was "satisfied" from weight, however proposed this as a potential improvement.

Most participants were "satisfied" and "very satisfied" with the texture of the puzzle-pot (fig. 97). Some noticed that it felt rather realistic: *"…the texture was lovely, it felt quite realistic for me"*. Five (5) people, though, gave texture neutral ratings. Amongst them, only one person's profession was related to CH. The comments people made or improvements they proposed with respect to texture were: *"Feeling the composite material is very different than the ceramic one", "If it was smoother than sticky"*. The tactile property of temperature was rated high by the participants too with twenty-three (23) positive ratings (fig. 98). Two (2) more ratings were neutral and one (1) negative. The participant, who negatively rated temperature, had also commented on the "composite" material of the pot and thus seems to have been influenced by the feeling of its texture. Durability was the last property that participants rated and their impression about it seems positive with twenty-four (24) ratings (fig. 99).

Finally, when people finished rating the properties of the puzzle-pot, they were asked whether they had any ideas on how to improve it. As mentioned previously, two people (2)

would want the pieces of the puzzle-pot to feel heavier, one participant wanted the texture to feel smoother, another one would want the texture to feel different than of a "composite" material and one mentioned that colour patterns would make the assembly of the puzzle more easy ("*Colour patterns would make the experience more child-led"*). Most comments with respect to the puzzle-pot were related to the lack of contextuality and location of the pot (mentioned before), along with some propositions about the lighting of the room and the flooring around the activity *("I would prefer the puzzle to be in a more visible/accessible position and the surrounding area of the pot to be softer for the falling pieces. The light could be a little bit better. The area was a little dark where we made the puzzle", "I think that the place where it's located it could be… If you place it in a more open space, I think it's better for the activity, for children to be aware of it and to enjoy it"*). Only one participant proposing improvements came from a CH related background.

7.5.4 The expression – perception of the experience

This section is dedicated in the qualitative analysis of the case study's findings. As in the previous cases, the analysis follows a mixed approach that examines data under the five main themes of the RXF, while allowing other significant themes to emerge (inductive and deductive approach, see 3.4.11). As mentioned before, some overlaps have occurred, due to data being coded under more than one themes.

7.5.4.1 Awareness/knowledge

All data related to the awareness or knowledge gained through the experience originated in responses to open-ended questions in the questionnaire and interview, as well as in a more precise question asking whether the experience helped people to discover more about the original urn, the gallery or the way archaeologists work. Participants' comments were coded under subthemes and are presented in table 28.

Theme: Awareness/knowledge	
Subthemes	**Quotes**
Awareness	*"My daughter enjoyed engaging in this activity and it was a nice way to introduce a context about archaeological finds."* *"Yeah, it gives them something to start thinking about more."* *"It's introduced him to the notion. So, when we do look at archaeology a bit more in the future, he will have that memory of the pot."* *"It made me really appreciate how incredibly satisfying would be to suddenly, to just find an amazing item, a prehistoric item like this!"*

Theme: Awareness/knowledge	
Subthemes	**Quotes**
	"Imagine if you were an archaeologist and you would find this on the ground!"
Making sense of something/broaden understanding	*"Again, it's just makes it much more tactile and much more real and brings it into the present time and gives you a better understanding of all."* *"I think so, yes. Because interaction of the whole thing is helping to memorize that urn, take it in more better."* *"I think if you want to understand more the history and the visualization, that's the word, yeah? I think it helps to memorize and understand better."*
Using previous knowledge/experience	*"We came really cause he wanted to see the ancient Egypt stuff and it has interactive things in there. And I think he's more likely to take an interest if there's games, he can play and he has been watching the programme called 'Horrible histories'."* *"What fascinated me, I don't know about the girls, was the… It was the pot from here, wasn't it? The original one was from Saltdean and I live just close to that, so that was interesting."* *"I just found out that it was in Saltdean it was found. So that's where his cousin lives so he has a sort of connection."*
Learning facts	*"Well, maybe seeing that that's the kind of pot they used to use. It was an urn, you know what that means (to his son). Well it is where you put ashes in, when someone's being cremated. When someone is burned after they died, we talked about that, yeah. We talked about that. So, he learned something."*
Difficulty in understanding/lack of learning	*"To be honest, I think we just thought about making the pot, we probably didn't think too much about the origins of the pot."* *"No, I don't think it had a new bearing on that, it was just fun."* *"No. To be honest it was more just a plaything."* *"I think that if the original pot had been more clearly close to it, then we would have realised that it was more."* *"What we've missed it was some information about the history of the pot . So, I've not had a sense of whether it helped us or not. I think that what we needed… we wanted to know more once we finished but we couldn't see anything written about the pot…"*

Table 28: Awareness/knowledge related to the experience of the puzzle-pot activity.

As shown in data, the activity of assembling the puzzle-pot affected participants more at an awareness and understanding level, rather than helping them to learn actual facts about the original urn. Hence, parents/carers mostly stated that the hands-on activity worked as a prompt to help children start thinking about artefacts and archaeology. Few parents also mentioned the idea of excavating and assembling the shards of a pot with direct reference to

archaeologists and the satisfaction of discovery of an artefact. Moreover, a number of comments relates the activity to enabling children to understand and make sense of the exhibition and pot through memorisation of the tactile interaction and shape visualisation.

As far as it concerns using previous experience, one participant mentioned that they came to the museum to expand knowledge acquired through a history themed tv show that their child watches and likes. Also, two participants who appeared to live locally, appreciated that the urn was found in Saltdean and were able to establish connections to the pot because of their background. However, only one of them had related the puzzle-pot to Saltdean prior to the interview phase. Such findings, along with the fact that only one person mentioned actual information about the urn during the interview, highlight the lack of contextuality for the puzzle-pot and point to the missed opportunity of directly relating the activity to the original pot on display. Participants' comments evidence such "difficulty in understanding" (further corroborated in 7.5.3) as most of them did not realise what the puzzle-pot represented and hence their encounter with the activity *"was just fun"*. Therefore, it seems that -even though fun and play are desirable and learning related aspects of such activity- there is great potential in providing an experiential framework that could affect families more holistically by providing an even richer experience and overall learning; something that constitutes one of the priorities in people's expectations from family museum visits (see 7.5.1).

7.5.4.2 Engagement/interest

Participants' comments with respect to enjoyment, engagement, fun, surprise, interest and more emotional aspects of the experience are presented in table 29. People's feedback about engagement came from the interview and questionnaire phase, when they were asked about their general impression of the activity and whether they particularly enjoyed any aspects of it. Furthermore, social verbal interactions -as already presented in 7.5.2- confirm findings especially with regards to interaction and collaboration of family members when assembling the pot, as well as general satisfaction upon finishing it.

Theme: Engagement/interest	
Subthemes	**Quotes**
Enjoyment	*"Well, the children really enjoyed trying to do it, so it was nice to have an exhibit that we could all do together."* *"I think it's good because you can do it with your son."* *"I think it's nice to be with the kids, to be hands-on."*

Theme: Engagement/interest	
Subthemes	**Quotes**
	"I enjoyed watching him enjoy." *"I think he really enjoyed it. I think he enjoyed it because it was a puzzle to solve."* *"My son likes puzzles and is a challenge for their age. Yes, it's a nice thing for them to do."*
Using senses	*"But it's just fun, we like -you know- we are tactile kind of people, we like touching things and that is great."* *"…to foster interest in these sorts of things. So, I really enjoyed it. I think that anything that can physically engage people with not just looking at things is wonderful."* *"I think it's good for the kids to have something to interact with rather than just looking at things. You know they are better at looking at things with their hands than just their eyes."*
Involvement	*"…it's really nice that the children can do something, and I think like that they become more motivated to get involved in that."* *"I really liked the idea that it gives you in a really… I know it's a very basic sense but in how these things can be pieced together -you know- on the process."* *"I think whether it's 3d printed or not, I liked the idea of it, 3d printing can replicate the objects exactly. But I think here, just to reassure the point before, is having an activity, an exercise that the kids can do and engage with, is what I enjoyed the most."*
Success/fulfilment	*"And in the end, when they finish, they are happy with it and then they can see the pot."* *"I think that especially for kids and see him (her son) doing it and the satisfaction he got from it. I think there's a really strong element of reward and fulfilment."* *"I enjoyed the… doing it with my son and the feeling of success. And that they both did it together."*
Reminiscence/memory recall	*"There is a great museum in New Zealand which has to do with movie studios with the Lord of the Rings and those other movies and they have a room where you can touch like faces like that and you can touch the hair, you can hold a sword and you can do all these things."* *"…and with taking my daughter for example to the museum in Berlin and where everything is hands-on…"*
Surprise/amazement	*"It was a nice surprise to have an activity in the museum."* *"I think with young children of this age is nice to feel and touch and actually... get involved. Nice surprise."*
Detailed exploration	*"So, really when you are making it you are really putting attention on the lines, on the colour."*

Theme: Engagement/interest	
Subthemes	**Quotes**
	"I thought it was good that my grandson was working out -you know- the rim, to look for the rim pieces to go at the top and then to fit in the rest of the pot, beneath the rim."
Imagination	*"And it creates like a portal to the time that this was from and for us that made it very special. Because it wasn't just sitting, it wasn't just something that was sitting in... as an exhibit, it suddenly became very real for us to interact with."*

Table 29: Types of engagement related to the experience of the puzzle-pot activity.

Data in table 29 reveal the wealth of engagements that the interaction with the replica puzzle-pot triggered. The majority of comments here were coded under the subtheme of enjoyment and evidence three aspects of the experience that people greatly appreciated: a. collaborating as a family; b. finding joy in children's joy (when adult did not participate); and c. being challenged to solve the puzzle. Using other senses apart from sight was another element that people referred to; something particularly important for children because they "are *better at looking at things with their hands*" as one parent stated. In the case of the puzzle-pot, though, tactility is further associated to involvement and interaction. A great number of comments explicitly focused on children's involvement with the activity. Nonetheless, one parent -while acknowledging the potential of 3D printing- stressed the importance of engaging with objects regardless of their fabrication method. Once finished assembling the puzzle, feeling satisfaction and enjoying a sense of success was another aspect people often commented about. This has been further evidenced through observations of families' reactions when completing the activity.

When discussing about engagement, four (4) participants recalled past visits in museums and compared their puzzle-pot experience to other activities. Often, people's quotes revealed an element of surprise as they were not expecting to find hands-on activities to enjoy with their children. Finally, few visitors talked about exploring details of the shape or decoration of the pot through the assembly and one parent discussed about the imaginative effect of the activity, enabling them to have a *"special"* experience with an object that became *"very real"*.

7.5.4.3 Attitudes

In order to "capture" the attitudinal aspect of the puzzle-pot experience, participants were asked about the value of 3D printed objects and similar activities in CH settings and whether

they would think differently about going to a museum with the family if they knew that such objects and activities exist. All representative themes with respect to attitudes can be found in table 30.

Theme: Attitudes	
Subthemes	**Quotes**
Opinions/values	*"I mean I think children especially get a lot of value out of touching things and -you know- often in museums that's the one thing you can't do, touch."* *"I think so, because if you have interactive objects that they can touch, they can use, the museum is more... It's more fun for them and I mean something that they always like."* *"So, I think actually moving and being involved physically, it brings a whole different dimension."* *"I think then... the children will think more about it… it's longer lasting."* *"I think it was more about connecting the kids with something to do -you know- the museum should be more of that and having activities which draw the kids and then peripherally as they can look around seeing great models and learn at the same time."* *"Very valuable. I can't impress enough because that makes things come to life. It makes it more real. Not just history, it makes it… it brings it into the present day, and I think that's fabulous."* *"I personally think it brings a completely different dimension to the experience of learning, it makes it more yours and it helps you participate in what you're learning and you feel much more like you're being transported to those times as well."* *"And that particular one is good because as a parent I can see he's not gonna break it. It's a robust thing."*
Attitudes of/towards/regarding organisations	*"Oh yeah, definitely. The involvement all around, as long it's something you can actually do, touch, makes... makes a difference."* *"Yes, it would. It would make more likely to visit if I thought that 3d printed objects were available."* *"Yeah. I think then the child will also like it more to come again because the children can be active, they can do something which they really like."* *"Definitely I would think of it more... I think particularly my younger daughter would be more interested but then my 6-year-old just started to read, and he can kind of interact more with more hands-on. I think all kids of all ages can join in. So yeah it would."* *"Um… It will certainly improve it. I don't know if it will change it because we are very... we love museums."* *"Yeah. I think it's- I mean we live in Brighton and I haven't been to this particular room before. We were meaning to come for ages and it's a nice surprise that it's a whole different selection of different ways of looking and touching and I think it's really valuable to be able to touch."*

Theme: Attitudes	
Subthemes	**Quotes**
Attitudes towards/about other people	*"I think it's good for children. It makes them more interactive with the items and increases their interest in archaeology."* *"It makes a huge difference because it becomes more interactive for them and that's the way, that is the primary way they learn."* *"But also, obviously for people who have sight disabilities, it's a way for them to engage with the museum as well."*

Table 30: Attitudes related to the experience of the puzzle-pot activity.

As shown in the table above, participants' responses coded under the opinions and values subtheme reveal that people appreciate opportunities for children to touch objects, as often they are not allowed to do so in a CH setting. Parents and carers stressed the importance of interacting with activities and artefacts as a means to: keep children physically engaged; entertain them; trigger their attention; and consequently, increase their overall interest in CH in the long-term. Furthermore, people commented on the ability of such experiences to "*make things come to life"* and bring another temporal dimension to the encounter with heritage objects. Interestingly, a parent also mentioned that handling a replica or the pieces of a replica activity removes the fear of damaging the original.

With regards to attitudes towards organisations, the majority of participants stated that physically interacting with 3D replicas would motivate them to visit museums more often (23 participants), especially as children would become more involved in the visiting experience. Two (2) participants emphasized the importance of interaction regardless of the fabrication method that has been deployed. However, interactivity with the particular puzzle has been enabled by the digital fabrication method that allowed following design requirements and future-proofing the exhibit in the first instance (as presented in 7.3.4.1). Hence, even though some people might not perceive the technology as being important, in reality the deployed technology made the production of such puzzle possible. In addition to these attitudes, one participant said that they would go to museums anyway, but such provision would "add value" to the experience. Amongst the visitors who would become motivated to go to museums with the family if 3D printed and hands-on activities existed, one also commented on how positively surprised they were that the Brighton Museum offered such a variety of interpretative means with emphasis on touch. Lastly, parents and carers discussed on how

3D replicas might affect children's interest and learning, while also mentioning the benefits for people with sight impairment too.

7.5.4.4 Skills

Assembling the puzzle-pot was an activity that required families and children to deploy a variety of skills. Puzzles have been long used as materials to support children from a pre-school age and on in developing perceptual and motor skills, problem solving, language and socialisation (Maldonado, 1996). Deploying such skills has been evident during the observation phase, when families collaborated and talked through the assembly, had to locate and place the missing pieces in order to solve the puzzle. In order to record further information with respect to skills, adult carers were asked during the interviews which were the skills their children and themselves employed for the puzzle assembly. Some of their representative comments can be found in table 31.

Theme: Skills	
Subthemes	**Quotes**
Communication skills	*"Definitely communication because it was a three-person team effort in the end."* *"I think yeah, communication between us both. I think that overall it's good for a parent and a child to do at the same time, I think I would have struggled to do it alone…"*
Problem solving	*"The problem solving. Fitting the pieces into the right section."* *"But it was -you know- it kept them occupied and they had to think about it."*
Motor skills	*"Yes, motor skills for children."*
Combination of skills	*"All of those things (skills). And even -you know- that I'd find shapes and gaps and mathematical…"* *"All of those skills, for sure, cause we had to communicate for the pot, we problem solved when we looked at the shapes and where they need to go. We had to be creative in our thinking, we had to observe and obviously make, practical… Yes definitely. I would say."* *"Making, practical skills, of course, observation."* *"Yeah, there was some communication and problem solving."*

Table 31: Skills related to the experience of the puzzle-pot activity.

Participants' comments corroborate in a way what has been observed during the puzzle assembly. Verbal and physical interactions (see 7.5.2) were part of the communication exchange between the members of the family groups when collaborating and many people referred to such interaction when interviewed later. Problem solving and motor skills are

other aspects of the assembly that fewer participants prioritised. Yet, the majority of participants discussed about a combination of skills (observation, motor, communication, creative thinking, making, mathematical and so forth) that were deployed when working to complete the puzzle.

7.5.4.5 Behaviours

All comments that refer to actions, possible changes in people's lives and progress that could involve further skill acquisition and learning have been coded under the behaviours theme. Behavioural data are closely related to attitudinal data, hence part of the comments presented in table 32 have been also coded under the attitudes theme (7.5.4.3). Another part of the behaviour related data resulted from awareness related responses (7.5.4.1), as well as responses that have been coded under the engagement/interest theme (7.5.4.2) and particularly the involvement/interactivity subtheme. Table 32 presents some of the characteristic behaviour related quotes.

Theme: Behaviours	
Subthemes	**Quotes**
Change in accessing information and CH organisations	*"I think obviously you can't use the real thing so the fact that you can use the 3d printed version is great, cause it allows you to see what exactly it looked like and touch it."* *"Yes, because it's something that's not in a case… so, it just makes it more intense the experience."* *"I probably wouldn't normally think to come here because it's probably not that interactive, maybe a bit outdated a bit older… But It was actually a nice surprise that there's other things here that are suitable for them I think."* *"I mean we live in Brighton and I haven't been to this particular room before. We were meaning to come for ages and it's a nice surprise that it's a whole different selection of different ways of looking and touching and I think it's really valuable to be able to touch."*
Future development	*"I'm just really impressed with this to be honest and that I feel like, as somebody who really loves learning through museums, I would love to see so much more of this."* *"I think it would just be nice to see more of it… Appreciate different media in one exhibition. It makes it more live."* *"Very interactive - great to connect the artefact to real life. There should be more examples like this."* *"I think it was great. The more the better."*
Learning desire or progression	*"I think it's good for children. It makes them more interactive with the items and increases their interest in archaeology."*

Theme: Behaviours	
Subthemes	**Quotes**
	"It's nice to have something to bring out some conversation." *"Yeah. I think, as I said, it's really nice that the children can do something, and I think like that they become more motivated to get involved in that."*
Participation	*"Imagine if you were an archaeologist and you would find this on the ground!"* *"It made me really appreciate how incredibly satisfying would be to suddenly... to just find an amazing item, a prehistoric item like this."*
Change in professional practices	*"I think for me, I'm a primary school teacher, so I'm always looking at different ways of trying to engage… Just of even… from a work point of view as well, whenever we take the children out to a workshop or some kind of engagement. Definitely brings that learning to a different level."*

Table 32: Behaviours related to the experience of the puzzle-pot activity.

The analysis of behavioural data emphasizes how the existence of replicas and hands-on activities not only changes the way people access artefacts through touch, but also makes the whole experience much more "intense" and relevant to visitors. Interestingly, such experience has the potential to change people's ideas about accessing an organisation, evidenced by participants' comments who were pleasantly surprised that Brighton Museum offers the possibility to approach CH in innovative ways.

Another aspect of behavioural data reveals families' desire to see more replicas and interactive activities in future as the variety of media and interaction *"brings things to life",* thus facilitating learning in the museum environment. This was further noticeable in awareness and progression themed comments, where people mentioned that the existence of replicas along with relevant experiences can enable conversations about cultural heritage and has the power to intrigue children making them more interested in artefacts and archaeology.

In terms of participation, some people's quotes relate the experience to the action of excavating and assembling the pot's shards as archaeologists do. Such data, apart from enhancing awareness about heritage work, illustrate how families can actually feel as being part of archaeological and conservation processes. Finally, a participant working as teacher highlighted how significant engagement opportunities are with regards to learning. Therefore, such experiences have the capability to transform the way that teachers work to facilitate learning.

7.5.4.6 Other themes

The themes in this section resulted from the RXF-based analysis and methods but deserve special attention. Hence, a conscious decision has been made to further present them separately here (see also 8.4.1).

The first prominent theme, that emerged from the data analysis, refers to **contextuality**. In this particular case, it was the lack of contextuality that many visitors mentioned or implied as a factor of the experience that prevented them from relating the replica puzzle to the original artefact. Further information about the puzzle-pot and even placing it close to the original could have affected the way that people experienced the activity and its overall learning, appreciation and interest-triggering effect. Some of the representative visitors' comments with regards to contextuality were:

"I think the main thing for me was that… it was too isolated and tucked away and if it was with other pots... there's a display in front of me with other pots… and the connection to the existing pot just wasn't there. So, to me it could be much better sort of activity if it was placed in context."

"I think that if the original pot had been more clearly close to it, then we would have realised that it was more (related to it)."

"We missed that there. We missed the original pot, so we saw the activity the kids were really excited, but then we missed the original pot. So, we would have loved to have an indication of that, yeah."

The opportunity to have a hands-on experience and the overall value of **interactivity** in the CH environment was another theme that many parents and carers emphasised. Part of their comments have been coded under the engagement/interest theme, but many more themes are also involved. Therefore, interacting with the pot has been an action that influenced different aspects of the experience such as:

- Increasing time spent with an artefact and hence positively affecting children to gain more interest in heritage objects and archaeology;

"I think it's good for children. It makes them more interactive with the items and increases their interest in archaeology."

"…it could definitely raise their interest of exploring the particular piece. Something that we might, for example, just passed by now with the interactive element we spend more time and attention."

- Making the experience more "fun" and enjoyable, while avoiding boredom and possibly affecting children's opinions about museums in the long-term;

"I think so, because if you have interactive objects that they can touch, they can use, the museum is more... It's more fun for them and I mean something that they always like."

"I think it's good for kids about this age because they are just getting bored just looking at things, so it's good if they can interact with it. It keeps them a bit more interested."

- Bringing another dimension to the experience that through interaction becomes more "real";

"Because it wasn't just sitting, it wasn't just something that was sitting in… as an exhibit, it suddenly became very real for us to interact with."

- Providing a sense of fulfilment with the completion of the activity;

"They participate and they feel fulfilled and rewarded from that and again it's like, they… we get transported to those times."

- Reinforcing learning including better memorisation of details about the artefact and beyond;

"Because… interaction of the whole thing is helping to memorize that urn, take it in more better."

"It makes a huge difference because it becomes more interactive for them and that's the way, that is the primary way they learn."

- Enhancing collaboration and communication between family members;

"Well, the children really enjoyed trying to do it, so it was nice to have an exhibit that we could all do together."

"Yeah, when she had to think about what she was doing and we did interact, so she didn't do it entirely on her own."

- Triggering memory recall with respect to past museum visits;

"I think that back to… in London, the Science Museum and the Natural History Museum where there's a lot more of those interactive activities which the kids enjoy a lot, and that's what draws them to come back again and again."

"There is a great museum in New Zealand which has to do with movie studios with the Lord of the Rings and those other movies and they have a room where you can touch like faces like that and you can touch the hair, you can hold a sword and you can do all these things."

- Expressing a desire for more activities of this type to become available in CH settings.

"I think it would be quite nice to have more things like this to do, perhaps largest scale and also with small pieces like that it could be quite nice to have some sort of interactive activity which is based on… models of settlements."

"I think there should be more examples of those kind of interactive things."

7.5.5 Children's artefacts and cards

Children's own artefact creations, 3d decorated shard-like pieces, along with textual information on cards was another source of data for this case study. Apart from constituting valuable sources of information (Nelson and Cohn, 2015; Yin, 2009, p. 113), similar types of data have been collected from children for research. In the visitor and CH context, children's drawings have been often used to shed light into different aspects of CH experiences. Some examples include assessing the effectiveness of message communication through exhibition design, evaluating children's overall learning, investigating children's reading of exhibits, perception and memories, museum space understanding and more (Coe, 1989; Diamantopoulou, 2008; Diamantopoulou and Christidou, 2018; Moussouri, 1997; Piscitelli et al., 2003; Studart, 2000).

The significance of drawings in examining children's ideas and perception lies within their self-motivation, free-play character, pleasure, goal-directed form of artistic expression and symbolic representation of "manipulations" and interpretations of their world, as described in psychology and child development literature (Dyson, 1990; Gardner, 1994; Piaget, 1952). Thus, drawings have the capability to "reveal" children's thoughts, ideas, cognition, feelings, emotions and so forth. In this case study, the purpose of artefact and card collection was to examine children's impression of the puzzle-pot activity through visual representation and textual statements. The goal was to gather further evidence from children about their experience with the activity through a free-choice act, i.e. decorating a shard piece the way

they wanted and writing what makes their piece special. In order to illuminate their points of attention, main experience outcomes and key patterns, children were rather left to express themselves freely, without giving them specific guidance on how to decorate their piece or what to write about it. Therefore, data from children's artefacts and cards not only refer to the visual impression of their ideas (what they drew), but also what they verbally stated (what they said about the picture they drew).

The overall strategy to analyse children's artefacts and texts on cards adopted an open inductive approach, where themes derived by the examination of objects and statements. Similarly to Moussouri (1997) and Studart (2000), the presence of features in artefacts (e.g. colours, designs, scenes) are the elements that demonstrate aspects of the perception of the experience.

Several other strategies can be deployed in conjunction with the thematic approach in visual methods research. Thus, a considerable body of literature is dedicated to examining drawings, often under the developmental lens. Just to name a few, Luquet's work discusses about four stages of drawings, the *Fortuitous realism phase*, the *Failed realism phase*, the *Intellectual realism phase*, and the *Visual realism phase*, which were later adapted by Piaget for his developmental theory (Luquet, 1927; Piaget and Inhelder, 1956). Then, Yavuzer suggests five stages that include the *Scribbling stage* (2-4 years), the *Pre-schematic stage* (4-7 years), the *Schematic stage* (7-9 years), the *Realistic stage* (9-12 years), and the *Visually naturalistic stage* (12-14 years) (as described in Studart, 2000). Lastly, Lowenfeld's artistic development stages, influenced by Piaget's theory of cognitive development, include the *Scribbling stage* (includes the Scribbling, 1-3 years, and Basic forms stage, 2-4 years), the *Preschematic/Human forms and early schemata stage* (4-6 years), the *Schematic/Emergence of visual schema stage* (7-9 years), the *Dawning realism/Interest in realistic drawing stage* (9-12 years) and the *Pseudorealistic/Adolescent artistic development stage* (12+ years) (Looman, 2006; Lowenfeld, 1947).

Theoretical classifications, such as the ones presented above, are useful in terms of understanding children's drawings. In the current research though, such perspectives have not been rigidly adopted, but have rather informed the data analysis. Hence, instead of deploying a particular theory, designs have been classified under rough age categories, presenting general characteristics of the artistic developmental phases (which are quite

similar in terms of age classification in most theories). Such approach has been consciously adopted, as generalisations could not be made due to the children's sample size and therefore tendencies are considered to be the most interesting aspects to investigate.

7.5.5.1 Decorated artefacts

Four categories emerged by examining the designs or scenes that children depicted on their pot-pieces. Table 33 presents the classification of designs and their quantitative distribution by children's age.

Decorative themes	Age distribution			
	6-7 years	8-9 years	10-12 years	TOTAL
Activity elements-blocks	7	3	0	**10**
Hybrid scenes	1	3	0	**4**
Imaginary scenes	11	1	1	**13**
Replica elements	1	1	0	**2**

Table 33: Children's artefact designs per theme and age.

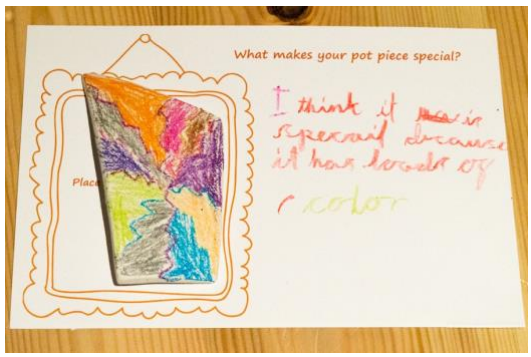
The main identified themes were:

a. **Activity elements-blocks** (fig. 100): Blocks, squares and coloured zones appear to be a common theme amongst children's decorations. Choosing to create colourful shapes that are interrelated on the surface of the artefact piece might have a reference to the fragmented pot and the activity of putting together the shards of the puzzle. Interestingly, seven (7) children amongst those who created artefacts with "activity elements-blocks" belong to the ages between 6-7. This is approximately the age when children transition from drawing *pre-schemata* to *schemata*. Schemata might exist in relationship with one another and often derive from existing knowledge; something that might be connected to the representation of the visual appearance and/or the assembly of the puzzle-pot.

"I think it is special because the colours make it special."

"My pot piece is special because I've used lots of colours to decorate my pot piece."

"It is beautiful."



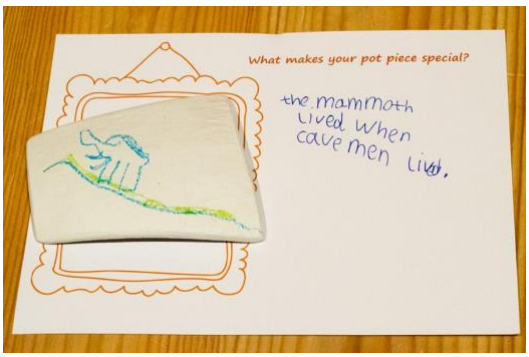
"I think it is special because it has loads of colours."

Figure 100: Children's artefacts and statements on cards under the theme "Activity elements-blocks".

b. **Imaginary scenes** (fig. 101): Imaginary scenes were the most popular depictions in children's artefacts. These include scenes that might have some reference to history or archaeology without being precise in terms of representing a specific artefact or event. In their majority, such scenes mix fantasy with reality or incorporate aspects from previous children's experiences (e.g. such as the movie *Early man*). Another part of the imaginary scenes includes objects, nature or even memory inspired themes that the children like or feel joy about. Most children that chose to present imaginary scenes belonged to ages between 6-7 years; something that could be related to the *pre-schematic* phase of drawing, when thoughts, emotions and ideas are illustrated with colours in non-realistic and often exaggerated forms.

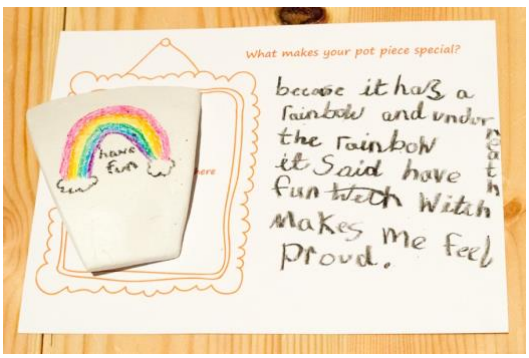
"It is special because it looks like a real fossil."

"It is a cave man kicking a skull. It is special because I am early man."



"The mammoth lived when cave men lived."

"It makes me special because it is pretty and it has loads of colours that reminds me about summer!!!"



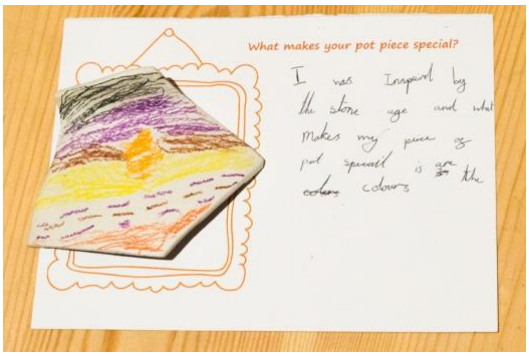
"Because it has a rainbow and underneath the rainbow it said have fun which makes me feel proud."

"It's like a spider net."

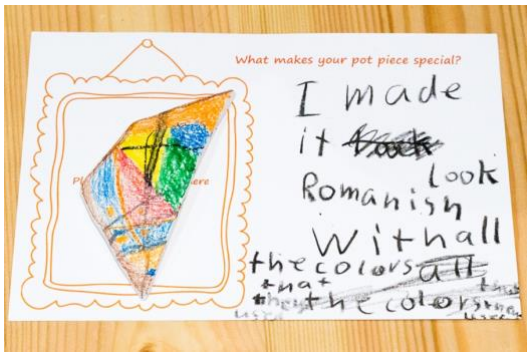
Figure 101: Children's artefacts and statements on cards under the theme "Imaginary scenes".

c. **Hybrid scenes** (fig. 102): Hybrid scenes include a mixture of elements, such as patterns of the original urn and puzzle-pot along with shapes or blocks of colour and even imaginary characters too. Some of the patterns the children drew might have originated in the curvilinear designs of the urn and replica (lines, dots, zigzags), while the coloured blocks infer the "activity elements-blocks" designs and the pot assembly. Lastly, the animal representation and the compass drawing might have derived from

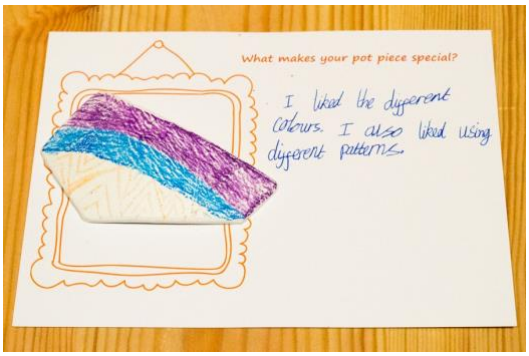
history related information as well as imaginary thoughts. Most hybrid scenes came from children aged 8-9 years, who are well into the *schematic* phase of drawings and are capable of representing knowledge, while organising elements with certain order.



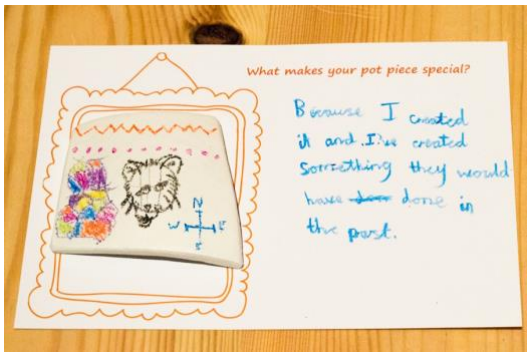
"I was inspired by the stone age and what makes my piece pot special are the colours."



"I made it look Romanish with all the colours that they used."



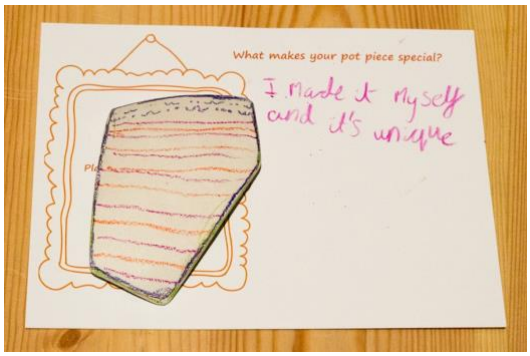
"I like the different colours. I also liked using different patterns."

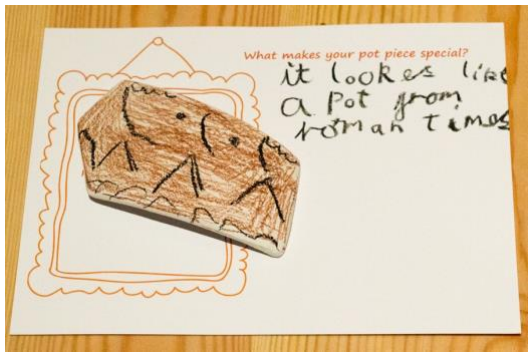


"Because I created it and I've created something they would have done in the past."

Figure 102: Children's artefacts and statements on cards under the theme "Hybrid scenes".

d. **Replica elements** (fig. 103): The most "realistic" representations that are closely related to the urn and puzzle-pot belong to this theme. The artefacts in this category present similar elements to the "hybrid scenes". Their difference though is that they do not seem to combine patterns with other "imaginary scenes" or "activity elements-blocks" designs. Moreover, the colours that have been used in these artefacts are close to the colours of the original urn and puzzle-pot. Two children between the ages of 6-7 and 8-9 created these artefacts. Hence, they were not into the *realistic* stage of drawings. These children had visited with the family other museums in the past, but only one of them had a parent with a CH profession. Therefore, there might be other contextual parameters that have affected their designs.





"I made it myself and it's unique." *"It looks like a pot from roman times."*

Figure 103: Children's artefacts and statements on cards under the theme "Replica elements".

7.5.5.2 Card statements

The children's statements highlight their opinions, ideas and aspects about the experience. Children's comments often describe directly what they have drawn on their shards. In many cases, verbal statements expand to further details that contextualise the designs. In other instances, statements' connection to the design is not obvious, at least to the external viewer. For these reasons, children's comments have been separately coded. Through the analysis four major themes emerged as seen in table 34.

Theme	Participants	Quotes
History and archaeology	9	*"I was inspired by the stone age and what makes my piece of pot special are the colours."* *"It is special because it looks like a real fossil."* *"It looks like a pot from Roman times."* *"I have seen people battling in other museums. This is how I got the idea for my fighting scene. These are spears being used."*
Hobbies	1	*"It is special because it is the colours of a football pitch and I like football."*
Joy of creation	12	*"It has my favourite colours on it. Red, turquoise and blue."* *"I think it is special because the colours make it special."* *"It is cute sandy and fluky."* *"I made it myself and it is unique."*
Stories they make up and scenes	4	*"It is like spider net."* *"I love the sun and nature."*

Table 34: Children's statements on cards.

Children's writings under the theme of "history and archaeology" refer to museum objects (pots, fossils, jars); animals (mammoths); historical periods (roman times, stone age, cave men); actions that might appeal to children (battling, fighting, kicking). All these could

evidence the artefacts that children noticed as well as the information that captured their attention, often mixed with previous experiences and scenarios they build with their minds. Under the theme of "hobbies" there has only been one comment of a child that loved football. In this case, the child preferred to connect his artefact to one of his favourite activities. Another small number of children (4) discussed about other things they like, such as the sun, nature, flowers, spider nets and even scary stories about ghosts. Preferences are present here as well; however, they mostly involve natural elements and stories the children make up.

Lastly, a great number of children's statements revolves around the joy of creation of the decorated shard itself and a feeling of satisfaction with the final result. In many instances, children emphasized the importance of colour and used adjectives with positive meanings to describe their impression about their artefacts (e.g. beautiful, unique, special, cute, pretty).

7.6 Conclusions

As data show in this case study, families constitute one of the "standard" museum audiences that often prefer to visit CH settings repeatedly. When they visit, they are mostly interested in finding things to do. For this reason, interactive activities are popular amongst them and people tend to spend time with activities, often driven by learning related motivations. Such motivations are reflected in expectations that link visits to further information acquisition and enhanced learning; often supported by interests in specific collections.

As far as it concerns the social context of the experience, it was observed that it was difficult for people to locate the activity and interact with it, when the visitors' flow in the gallery was heavy. On the other hand, when there were people interacting with the pot in a non-crowded environment, other visitors would become interested in it and wait their turn to have a go at the puzzle; something described as "modelling behaviour" in visitor research (Falk and Dierking, 2013, p. 154; Vom Lehn et al., 2005). As for the physical interactions between the members of a family group, these included gestures to motivate children to try the activity; physical guidance; moving pieces and core while assembling the puzzle; and expressions of celebration in the end. Additionally, verbal interactions reveal a wealth of communication prior, when assembling and after completing the puzzle. However, in some instances people wondered what the relation of the puzzle-pot to other artefacts in the Iron Age section is.

When examining the physical context of the experience, it becomes clear that people's attraction to the activity was also affected by the location of the puzzle, as this was almost

hidden in a busy area of the gallery. Hence, an adult would often notice the activity and then motivate children to interact with the pot. Assembly was always successful, and nobody quit. In fact, the level of difficulty of the puzzle was positively discussed. What was missed, though, was the opportunity to relate the puzzle replica to the original urn on the opposite display, due to lack of interpretative information. Such lack of contextuality was emphasized by the participants, as shown in qualitative data. More information on the puzzle-pot, placing the activity at a 360-degrees accessible, noticeable area and at a height where younger children could reach it, are some improvements that could maximise the prospect of the activity.

As for the sensorial performance of the puzzle-pot, ratings were very positive. Nonetheless, it should be noted that people have had the opportunity to relate the puzzle-pot to the photo behind it, but not to the original urn; something that could evoke comparisons, affecting rating as well. Some of the improvements proposed by participants about the properties of the replica pot were to produce heavier pieces and make texture more realistic.

The potential of the puzzle-pot activity is further highlighted by the analysis of the qualitative data. In terms of knowledge, data show that the activity has affected families mostly at an awareness and general understanding level. Hence, the activity was seen as an opportunity to prompt discussions about archaeology in general. However factual learning about the specific artefact was missing. Some connections to previous experiences were also noticed, but these often came at a later stage, when people realised where the pot had come from. Thus, the lack of contextuality seems to have affected richer learning and prevented families from establishing further connections to the pot. On the other hand, engagement data have been particularly broad, illustrating how people enjoyed the activity, appreciated the chance to become involved in the assembly and collaborate in resolving a challenge, while also experiencing a sense of satisfaction when completing it.

With regards to attitudes, it seems that replicas and similar activities would motivate families to go to museums more often. The importance of replicas and interaction was particularly emphasised as means to physically engage children, trigger their interest and enhance their CH experiences. In general, interactivity has proved a significant element of the experience and is related to a variety of themes in data analysis. Few participants, though, stressed that it is interactivity and not the fabrication method, which is the most important. Yet, the nature

of the puzzle replica is directly connected to its digitisation and fabrication aspects that enabled establishing such interactions in the first instance.

As people stated, a variety of skills were also used to resolve the puzzle and communication was enhanced during the activity. Moreover, assembling the puzzle affected people at a behavioural level, as similar experiences can change the way families access CH information, strengthen learning desire, participation and imagination. For this reason, many participants expressed their wish to see more similar objects and activities available in museums in future.

Finally, children's artefacts and statements reveal the variety of engagements that young visitors experienced. Some of them established more obvious connections to the shape, appearance and assembly of the pot, while others represented imaginary themes, often influenced by history and archaeology. Fewer children made drawings that were more closely related to the pot, while other children mixed elements in hybrid scenes. The joy of creation was particularly evident in their comments and many statements were related to CH information. However, what was truly remarkable to notice is the wealth of thoughts, scenarios and ideas that children impressed on their artefacts and written expressions.

7.7 Summary

This chapter presented the third case study of the research. The first part was dedicated to the design of the case study, which involved the production of a replica puzzle-pot for families to interact with, representing a funerary Iron Age urn from Saltdean. Then the data collection and pilot study were discussed, and the analysis of findings followed. The RXF has guided the analysis of data in this case too.

The results of the case study reveal how each family might have different expectations when coming to the museum. These are often driven by personal interests and learning related goals. Hands-on activities are appreciated by families and a variety of social interactions occur when working on an activity such as the puzzle-pot. Yet, many aspects of the experience are affected by factors related to the social and physical environment of the activity. In the overall, some of the main remarks of the study are that replicas and similar interactive activities have the potential to transform the museum visit into a pleasant and often collaborative experience that can increase children's awareness and trigger their interest in CH. Such experiences would make families to go more often to museums and hence many

people expressed their desire to see more replicas and hands-on activities in museums in future.

The final chapter of the thesis follows. The chapter discusses across-case remarks and presents the conclusions of this thesis.

8 Chapter 8: Across-case examination and conclusions

8.1 Introduction

The final chapter of this thesis is dedicated to the across-case examination as well as the overall conclusions of the research. In the first instance, by acknowledging that in-depth analyses have been possible at a case level and by recognising the highly contextual factors of each study, the across-case examination constitutes a *reflection* on convergent or divergent information from all case studies. The purpose here, as stated in section 3.4.6, is not the statistical generalisation of the research, but rather the analytical generalisation of the theoretical proposition, which aims at informing decisions with respect to the incorporation of digitally fabricated artefacts as interpretative means in CH experiences.

The conclusions part of the chapter can be found from 8.3 and on and includes: considerations and recommendations for the whole lifecycle of digitally fabricated artefacts' integration in heritage experiences; a review of the value of the RXF along with guidance for its deployment; a detailed presentation of how the RQ and related objectives have been addressed; a restatement of the thesis' contribution; as well as reference to future work.

8.2 Across-case examination and reflection

This research project was carried out to "decode" replicas and then investigate their contribution as novel interpretative devices within realistic CH experiences for specific target audiences. Three separate case studies were designed to address questions related to the digitally fabricated artefacts' dynamics and perception by different audiences. For the case studies, an effort was made to include artefacts of different nature and/or chronological periods: an environmental display or diorama from the Booth Museum; a replica pot designed by Pablo Picasso; and an Iron Age funerary urn from the BMAG. All objects were selected in collaboration with the professionals of the RPM, with the aim of benefiting both the research and the museums' work. The selection of audiences was also influenced by the RPM's development plans, while taking into consideration research discussing about the people that can benefit the most by encountering replicas (see 2.5 and 3.4.9).

In order to holistically examine audiences' experiences with the digitally fabricated artefacts, the research followed a systematic approach through the adoption of the RXF. Hence, the research was driven by a theoretical proposition that acknowledges the significance of

context in heritage experiences. For the same reason, an in-depth situation analysis through the three case studies was opted instead of an experimental research design. From the methodological point of view, this in-depth examination was further enabled by the multiple-case design. Thus, the findings of each case study have been detailed separately, while the examination of all cases -and hence convergent or divergent information as it emerges from them- is presented here. The following section constitutes an examination as well as a *reflection* on the overall findings, including how audiences' expectations were met, how requirements were shaped and how replicas were perceived within the CH experiences.

8.2.1 Contextual remarks and implications

8.2.1.1 Visitors, their background and expectations

In all cases, participants interacted with the replicas and were observed (and for the first case study video recorded) by the researcher. As soon as they finished, they were asked to fill in a questionnaire and respond to the questions of the semi-structured interview. Information on the visitors' background and personal context was gathered as part of the questionnaire in order to allow data cleaning and analysis.

8.2.1.1.1 Visitors' demographics and tendencies

Amongst the eighty-three (83) participants who took part in the research, forty-five (45) were women. In the first case study, male participants were more (15) than the female participants (10). In this case study, most of the participants did not participate in the context of an actual visit in the museum and it seems that more men were interested in participating in the research. Another factor that might have played a role is that most members of the Blind Veterans seemed to be men. In the other case studies, however, women's numbers are higher, and it was noticed that in the museum environment women were more numerous; women were more willing to take part in the research; or men were happy to give their place to women. Relevant remarks, though, about women's presence in heritage settings have been corroborated by research (The Audience Agency, 2018).

When examining people's age, it becomes obvious that this was determined by different factors in each case study. Hence, in the first case study younger participants came from CERB, which has an educational and vocational character; whereas participants from the Blind Veterans were older. Even though the final age distribution in this case study resulted relatively balanced, the institutional character of the data collection sessions highlights the

difficulties when doing research that involves visually impaired audiences, due to the lack of provision in societal and infrastructural terms that would allow free movement and access to CH settings (amongst other places). In the second case study, that involved random adult visitors, it was noticed that most participants belonged to groups above the age of fifty. Again, this is evidenced in research about museum audiences' age and trends in population ageing (Matty, 2004; Reeve, 2009; The Audience Agency, 2018; United Nations Department of Economic and Social Affairs, 2020). In the last case study, where the target audience were families, age groups are justified by national statistics related to the age that most people have children. Fewer participants were older and, even though there were some parents/carers belonging to groups above the age of fifty (50), there were not many grandparents visiting the museum with their grandchildren.

As far as it concerns ethnic background data that were collected in the kittiwake diorama and the Picasso pot studies, it becomes obvious that BAME participants were very few (6 for both case studies). Even though one case study mostly investigated people's interactions in an "institutional" context and the other one in a museum context, in both cases BAME people are underrepresented. Such remark, might highlight difficultly in accessing disability support infrastructure as well as lower numbers of BAME people visiting museums, as corroborated by national statistical data (Department for Digital Media Culture and Sport, 2019b).

8.2.1.1.2 Visitors' past experiences and occupation

With respect to previous experiences, it seems that most people had visited other settings in the past and only one visitor in the Picasso pot case study was visiting a museum for the first time. A noteworthy remark about previous visits, is that -not surprisingly- very few visually impaired people had visited the Booth museum before (2 out of the 11 participants), even though many live at a relatively close distance to it. Families, on the other hand, had all visited museums with the children before. For the vast majority of them, coming to the Brighton Museum was a repeat visit; something that research reports as regular families' behaviour (McManus, 1994). Another topic of investigation was people's past or present occupation and whether this belonged to the wider CH context. Amongst the eighty-three (83) participants, there were eighteen (18) people with heritage related occupation. Their experience seems to have influenced some aspects of the expression and perception of the overall experience as documented in qualitative data. Moreover, when investigating if people had the opportunity

to touch objects in heritage settings, the vast majority of those who mentioned past tactile experiences had a heritage related occupation and often a "privileged" access to artefacts. Further background information also reveals that people's age plays a significant role as far as it concerns IT use in museums and older participants might not feel comfortable to deploy complex interactive media in exhibitions. Most families, whose involvement did not include any IT multimedia application, had experience in using hands-on activities and this is an element that attracts them to a heritage setting as triangulated by qualitative data (see 7.5.4.2, 7.5.4.3, 7.5.4.6).

8.2.1.1.3 Visitors' interests and expectations

Lastly, people's expectations and interests seem to influence their visits to museums (Falk et al., 1998; Falk and Dierking, 1992, 2013). Hence, it does seem worth to see how people's interests and particularly expectations were met through the experiences with the digitally fabricated artefacts.

In the first case study, the "institutional" character of the data collection sessions is reflected in participant's comments on providing feedback for the research. Likewise, their interests are rather generic, as most had no specific interest or had general interest in the collections. Yet, it seems that expectations and interests of the visually impaired community -as particularly evidenced in behavioural data (5.5.4.5)- can be influenced by *accessibility*, both in terms of general museum infrastructure and at an exhibit level. Thus, it could be argued that accessibility -as facilitated by the nature and properties of the 3D printed relief itself along with its complementing application and possibly other interpretative media (e.g. organic materials to touch, such as feathers and plants to counterbalance the lack of realistic textures)- has the potential to "render" visually impaired users' expectations and interests as far as it concerns their CH experiences. To enhance accessibility and increase interest and motivation, CH organisations could take advantage of the 3D digital representations of artefacts in additional ways. For instance, accessible 3D models of artefacts can be made available online so that visually impaired people with fabrication technology means could download, print them and experience them at home, at a group gathering or before/after the visit to the museum.

In the other two studies, where the encounters with the digitally fabricated artefacts were of a less "scheduled" character, most people stated that their expectations were related to

exploring a specific collection when visiting the museum. Sometimes, expectations were also "translated" into specific interests. Apart from the exploration expectation, other strong tendencies in people's expectations include their desire for inspiration (with the purpose of creating artwork or learning-related inspiration) as well as learning per se. In the Picasso pot study, exploration, learning and inspiration aspects seem to have been better covered, as evidenced in people's *awareness/knowledge* (6.5.4.1) and *engagement/interest* (6.5.4.2) quotes. This could be associated to the "accurate" representation of the properties of the digitally fabricated replica, as well as the existence of a variety of interpretative means, in conjunction with the presence of the original artefact close by.

In the case of the Saltdean puzzle-pot, learning in terms of including richer *awareness/knowledge* effects is less obvious (7.5.4.1), because of the lack of contextuality that influenced families' perception of the replica puzzle-pot itself and of the overall experience. Due to the character of the activity, *engagement/interest* comments are more prevalent (7.5.4.2). Hence, parents'/carers' expectations with respect to more factual learning goals might have not been successfully addressed. On the other hand, interactivity through the challenge-like nature of the experience has been deeply appreciated by families (7.5.4.6) and appears to have positively affected them at multiple perceptual levels.

8.2.1.2 Social aspect and interactions

8.2.1.2.1 Composition of visit and social environment

The examination of the social aspect of the experience in each case study comprises information, in the first instance, about the composition of visits. A noteworthy remark here is that in the first case study, some "helpers" who were accompanying visually impaired people, tried to "take over" and respond themselves or influence the participants' responses. It was also observed that visually impaired users were quite often relying on their helper in order to perform simpler of more complex tasks. Such remark, triangulated by qualitative comments about self-esteem and freedom (see 5.5.4.3), emphasises the need to provide equal opportunities to enable disabled audiences to access CH information -as much as this is possible- independently. Independent exploration can be facilitated by digitally fabricated replicas, such as the kittiwake relief complemented by audio and other media, but would definitely work best if the provision for visually impaired audiences was holistic both in terms of accessible digitally fabricated exhibits and overall infrastructure.

In the Picasso pot case study, most people came as part of a group and in the third case study visitors constituted family groups; both being popular museum audiences as visitor research shows (The Audience Agency, 2018). The social character of the composition of visit in the Picasso pot case was not "disturbed" by the replica. In contrary, the replica engaged visitor groups and prompted dialogues between people. In the Saltdean urn puzzle-pot, though, the group character of the visit could have been better supported by design choices that would facilitate easier access to the puzzle-pot and group collaboration.

In all cases, the social environment and whether a location was busy and crowded influenced the overall experience. The environment was more "controlled" in the first case study with visual impaired users. In the second and third study, though, at the Brighton Museum, visitor flows have affected the way people experienced replicas in terms of enabling them to pay attention or even locate replica activities. This was particularly obvious with the Saltdean puzzle-pot whose physical location significantly affected the overall experience (see 7.5.3).

8.2.1.2.2 Social interactions

The social context investigation included evidence about the physical and verbal interactions as they emerged through the encounter with the replicas. Interestingly, physical motivation/movements or nodding to another person to touch, try the activity or look at the replica were present in all studies, showcasing an interest to socially share the experience of the replica. In the visually impaired and family audiences case studies, where the exploration had a more "active" character, elements of physical guidance and collaboration were further present, as well as ways to express satisfaction and celebration when locating elements of the kittiwake relief or when completing the puzzle. Other physical interactions in the puzzle-pot case study included a sort of competition between family members (e.g. children pushing each other); lifting a child to take part in the assembly; and imitating visitors' behaviour. On the other hand, the Picasso pot case study seems to have had a "freer" character and therefore triggered some more "imaginative" physical (socially-sensed) interactions, such as whistling inside the pot and pretending to pour water out of it.

Likewise, verbal interactions in the kittiwake relief and the puzzle-pot studies revolved around themes related to motivation to touch and perform the activity, guidance, corroboration of findings and satisfaction/celebration when the exploration or activity had finished. In the Picasso pot study, where the correlation to the original object was more obvious and the

exploration did not involve any physical tasks, people discussed more about the object itself, the artist and the resemblance of the replica to the original.

8.2.1.3 Space, media and requirements from replicas

8.2.1.3.1 Space, environment and attraction to replicas

The setting and the physical location of each digitally fabricated artefact were examined first in each case study. In the visually impaired users' case, the location of the Booth museum might have been more "realistic" in spatiotemporal terms, however people seemed more comfortable in premises designed with accessibility in mind and hence this is something that museums should further elaborate in terms of establishing accessibility at a micro and macro level. In the other case studies, placing replicas near gallery "exit points" and in narrow, occluded and busy areas of the exhibition has affected interaction and attraction to them. Yet, in the Picasso pot study the central location of the replica and its close connection to the original appear to have counterbalanced -up to a point- such effects. With respect to replica attraction, in the kittiwake relief case study, this has been clearly affected by the existence of clear guidance; something that agrees with the general remark about accessibility that should be addressed holistically. In the Picasso pot study, people were attracted by the replica and were curious about it (6.5.3), but felt surprised and demonstrated "modest" behaviours when touching it. In the puzzle-pot study, adults acting as "facilitators" motivated children to interact with the activity (Falk and Dierking, 2013, pp. 153–154), but this is probably related to the physical location of the pot, as adult motivation was not needed for other gallery activities that were immediately noticed by the children.

8.2.1.3.2 Interpretative media

Attraction to interpretative means in the kittiwake relief study was largely determined by the type of each user's impairment and skills. Hence, the participants whose sight did not allow them to distinguish the elements on the diorama or mobile application screen, paid attention to the relief and audio. Similarly, when tactile skills were weak, audio was preferred as a medium to support interpretation. Braille, on the other hand, has proved a desirable addition to the relief as the majority of readers were able to read it and commented positively on it. In the second case study, the digitally fabricated Pot Oiseau seems to have attracted people's attention for considerable time without distracting them from the original. In fact, most people appreciated all interpretative means. Thus, the pot replica in the given interpretative

context was a valuable addition. The importance of context is further evidenced in the puzzle-pot study, where families paid attention to the replica puzzle activity and the photo behind it but missed the relation to the original urn. This happened because the puzzle was placed separately/away from the urn and further clearer interpretative information did not support users in establishing connections to it.

8.2.1.3.3 Usability

When examining usability aspects in the kittiwake relief and application study, a careful and abstracted representation of the original exhibit's main features, a seamless function of the application and a well-designed audio appear to have been appreciated by users. So did the more "holistic or experiential" aspect of the usability examination. Traditional task-based tests were negatively discussed by people with sight difficulties, when recalling other examples of resources and applications and comparing them to the relief experience and evaluation. As far as it concerns functionalities, facilitated by software to allow voice controls and voice reading on a mobile application, these also appear vital for visually impaired audiences.

In the Picasso pot case study, an interesting short video that highlighted key parts of the narrative around the exhibit received positive ratings by the visitors. Written guidance in the form of the label that invited people to touch has also been crucial to facilitate tactile interaction with replica pot. As far as it concerns the puzzle-pot study where usability was mostly related to the ease of assembly and satisfaction, the size of pieces, the visual cues (lines on core, painted decoration), the magnets and the rotation of the core have all helped families to put the puzzle-pot together; while the level of difficulty of the assembly and overall satisfaction from the activity got positive ratings/comments too. Access from 360-degrees, though, could have made the collaborative assembly easier and more appropriate height could have allowed younger visitors to participate.

8.2.1.3.4 Sensorial preferences as audiences' requirements

As far as it pertains the fabricated objects' properties, even though it is not possible to draw conclusions in the aggregate -because each case study involved a different artefact/replica, target audience and type of interaction- it has been possible to perform an in-depth analysis of each replica, while detecting some across-case tendencies. This happens, because the sensorial properties' classification enables to develop an understanding of the replicas'

features that were quantitatively (through rating) and qualitatively (through open-ended questions in questionnaire and interview) examined.

Hence, in the *kittiwake relief study*, size reduction, weight (and portability), temperature of the material and durability seem to have worked well for blind and partially sighted users. However, some users found it difficult to rate the last two. As far as it concerns shapes, there is room for improvement, as some of the diorama's elements could have been "depicted" more clearly (e.g. whelk eggs). Such finding could be further associated with the need of effective algorithms and automated or semi-automated techniques to extract 3D shape from an image, while providing an appropriate level of abstraction for the visually impaired. Full 3D representations would also be desirable, yet the nature of the encased display did not allow performing a full 3D acquisition and fabrication of the diorama. Alternative means to experience dioramas in full 3D could be developed too, while balancing the advantages and disadvantages of each approach for a given project. As far as it concerns the relief, another property that could be improved is texture. Here, the lack of suitable fabrication methods to represent natural materials (e.g. feather, plants) becomes obvious. When it comes to colour, a general solution would not probably fit for all as each individual possesses different visual capabilities depending on each type of impairment.

A summary of the audience's requirements as they emerge through the examination of the properties of the 3D printed relief is presented below. These requirements belong to the intrinsic sphere of the relief and are the ones that can be addressed by 3D processing and digital fabrication (often called *non-functional requirements* in the IT domain). Some across-case properties' tendencies (that can be addressed through editing and fabrication) are repeated in 8.3.2, along with more general, extrinsic or experiential requirements (often called *functional requirements*) which are "translated" into general recommendations. Thus, in the *kittiwake relief* case study, properties' (editing and fabrication) requirements are:

- Size: A portable relief representation down to the size of an A4 page works well to allow for comfortable exploration and identification of an abstracted diorama. This size fits in most medium FDM printers.
- Shape: A level of simplification is essential to declutter representations and allow for comfortable identification of elements. Choosing the right elevations should be determined by guidelines as presented in 5.3.3.1. The inclusion of Braille (guidelines

in 5.3.3.1) is useful too. Complex shapes should be abstracted. An effort, though, could be made to present some of their details.

- Weight: A relief should be light enough to allow for portability and easy transportation, without compromising its durability.
- Texture: Textures should be as close as possible to the originals. The representation of organic-like materials can be substituted by using complementary interpretative means (e.g. sponge, feathers) until a satisfactory solution is developed through digital fabrication.
- Temperature: A temperature that allows for comfortable exploration seems to work well.
- Durability: A relief, as well as every digitally fabricated artefact, should be made of durable, safe materials as it will be handled by many people.
- Colour: There is no one solution that suits all. Alternative coloured depictions could be provided to partially sighted people in the form of coloured reliefs or coloured prints could be offered in conjunction with non-coloured reliefs.

In the *Pot Oiseau case study*, visual properties received high ratings and most people approved the appearance of the pot. However, reflectance and gloss had increased neutral ratings; something that -along with qualitative comments- confirms that some people found difficult to rate. Size, shape and texture were also rated positively, but some scepticism here emerged. The majority of visitors approved the weight, temperature and durability of the replica. Nonetheless, the desire to compare the replica's weight to that of the "original" pot was something that users highlighted, along with some hesitation when rating temperature and durability. Some of the improvements that people proposed concern: the durability of the replica's materials; the incised decoration; and the gloss/protective coat of the replica. To summarise audience's requirements, as they emerge through the examination of the properties of the 3D printed pot, and the way that they can be addressed by 3D processing and digital fabrication, these are:

- Colour: It should be as close as possible to the original artefact. If the colours of the digitally fabricated object do not appear "faithful", other artistic means can be deployed to colour replicas (depending on available resources).
- Brightness: Same as colour.

- Reflectance, Gloss: They should be as close as possible to the original artefact, restricted to the area where they appear. Manual artistic work might be needed to satisfy users' requirements (e.g. by applying some varnish).
- Size: Size should be "accurately" replicated. In case the object does not fit into a printer's deposition bed, it can be fragmented, printed and then pasted together.
- Shape: Shape should be "accurately" replicated, and further manual work might be needed to improve minor decorative details.
- Weight: Should be as close as possible to the original, while enabling safe handling. If exact replication through digital fabrication is not possible, weight can be added manually (e.g. by pouring plaster inside a pot) and it is easier to add than to remove volume.
- Texture: Textures should feel realistic and hence be as close as possible to the original. Ceramics could possibly be replicated in suitable printers. If there is no access to a ceramic printer, materials do not appear stable or there are safety considerations, manual post-processing can imitate ceramic-like materials.
- Temperature: A temperature that allows for comfortable exploration seems to work well.
- Durability: As every digitally fabricated artefact, a pot should be made of durable, safe materials as it will be handled by many people.

In the *Saltdean puzzle-pot replica study*, the overall sensorial rating of the replica was positive. Satisfaction from the visual properties was high, however some neutral ratings appeared when examining brightness, reflectance and gloss. All participants were satisfied with the puzzle-pot's size and shape. The rest of the tactile properties got positive ratings, with some neutral responses that either reflect a desire for improvement (e.g. the texture or weight of the replica pieces to be closer to ceramics) or a difficulty to rate some of the tactile properties. Many of the improvements that people proposed refer to the lack of contextuality for the puzzle activity; a fact that might have also affected sensorial rating.

Audience's requirements, as they emerge through the examination of the properties of the 3D printed puzzle-pot are:

- Colour: Colours should be as close as possible to the original artefact and should not be omitted as they facilitate assembly (through visual patterns). If "faithful"

representation of colours cannot happen through fabrication, other artistic means can be deployed.

- Brightness: Same as colour.
- Reflectance, Gloss: They should be as close as possible to the original artefact, restricted to the area where these appear. Manual artistic work might be needed to satisfy users' requirements (e.g. by applying some varnish).
- Size: It will have to be appropriate for the target audience and for assembly, following relevant guidelines (see 7.3.4.1). Scaling-up or down a pot might be a necessary part of the 3D model editing, depending on the size of the original.
- Shape: Shape should be as "accurate" as possible for the whole replica, but piece shapes will depend on the above-mentioned guidelines. Assistive "cue shapes", such as the core for the puzzle along with a stable part around the pot's base can facilitate assembly.
- Weight: Weight should be as close as possible to original pottery shards of similar size. This can be partly controlled through density in digital fabrication.
- Texture: Textures should feel ceramic-like, but in order to achieve such feeling for pieces that will have to withstand heavy handling a more manual approach might be needed (e.g. covering a stronger material with marble plaster).
- Temperature: A temperature that allows for comfortable exploration seems to work well.
- Durability: Puzzle-pieces should be made of durable, safe materials as they will be handled by many people, including children.

When conclusively examining the sensorial findings, some of the across-case tendencies that emerge illustrate that:

- people appreciate the "accuracy" of digitally fabricated artefacts with respect to the original objects they represent; they also tend to compare replicas' properties to the originals', when this is possible (as reflected in visual and tactile ratings and comments);
- some people might encounter a difficulty when rating properties that require a "deeper" visual (brightness, reflectance and gloss) or tactile (temperature, durability) examination and understanding;

- there is potential to improve replicas' textures by developing more advanced fabrication methods (e.g. to effectively print coloured ceramics, objects with natural-like materials);
- replicas need to feel durable, and should also be safe for handling;
- sensorial ratings and suggestions for improvement do not seem to be clearly related to people's CH profession (18 people with CH profession in the research), as in order to establish definitive associations a larger research sample (and research design aiming at generalisations) would be needed. However, part of those encountering replicas with scepticism or proposing improvements seem to belong to a more "demanding" audience that often has CH connections and background.

An overall remark is that in all case studies the goal was to produce replicas as close as possible to the original, while taking into consideration contextual parameters (audience type, exhibition, location, interactivity etc), including feasibility of production processes and availability of resources. Such strategy, apart from being realistic, seems to have proved correct, because the overall visitor satisfaction and positive comments.

8.2.2 Perceptual and expressive effects

The encounters that the target audiences had with replicas were further investigated with respect to the perceptual or expressive aspect of such experiences. In order to "decode" the meanings, values and significance of digitally fabricated artefacts, the expression of the CH experience was analysed by following the RXF. While acknowledging the importance of contextual factors and thus the great perceptual variation for every case and individual, some conclusive reflection on the experiences with replicas is presented below.

8.2.2.1 Knowledge/awareness implications

In all case studies, participants were affected at a knowledge and awareness level. Nonetheless, making sense of the exhibit, learning facts about it and even expanding factual information appear to have mostly happened in the first and second case study. The lack of contextuality in the Saltdean pot study (as a result of the location of the activity and the absence of interpretative means) has clearly prevented families from learning more about the urn, its function, provenance and other types of information. Such finding comes in contrast to families' expectations that are often aimed at learning (see 8.2.1.1.3). Conversely,

increased awareness around the exhibits has been a prominent effect of the experiences. Many visitors made use of previous knowledge and experiences, while interacting with replicas. However, a small part of the audiences found it difficult to understand or learn from a replica; a remark that can be associated to the replicas' properties, people's skills, lack of interest or contextuality of the activity.

8.2.2.2 Engagement/interest implications

At the engagement level, there is evidence showcasing the wealth of connections that visitors established and the interests that were triggered through the interaction with replicas. In all case studies, many participants enjoyed using their senses; a fact that becomes particularly important for visually impaired users, whose tactile explorations constitute "windows" to the world. Same happens with children, who build interpretations of the world through actual interaction based on the constructivist approach (Coren et al., 1999; Falk and Dierking, 1992; Jensen, 1999). In the kittiwake and Picasso pot studies, some of the elements that people enjoyed the most are the replicas' sensorial features and the information around the exhibits. In the puzzle-pot study, the joy of collaboration and challenge of assembly were aspects that people emphasised. Moreover, in the first and second case study there have been particularly vivid comments of surprise, referring to the replicas themselves or the possibility to touch. In the Saltdean urn case study, numerous comments focused on the opportunity to become involved in a hands-on activity. Memory recall, emotional reactions, joy for the exploration and inspiration have also been effects of the experiences with replicas. However, there have been few visitors that were less interested or found interaction with the replicas rather difficult.

8.2.2.3 Attitudinal implications

The attitudinal analysis of the experiences with the digitally fabricated artefacts reveals people's opinions on the value of replicas as interpretative means as well as implications of their incorporation in the CH context. Hence, in the study with the visually impaired users, the analysis emphasises the lack of opportunities to haptically engage with artefacts and how such provision would allow people to experience heritage assets independently, while enhancing their sense of confidence and freedom. Consequently, the existence of replicas could essentially become an act of recognition of the visually impaired people as equal audiences for CH settings, as many users stated. In the Pot Oiseau study, the attitudinal

findings demonstrate that visitors appreciate replicas as means to allow physical engagement with objects; something that transforms the museum visit and has the potential to deformalise CH experiences. Similarly, in the Saltdean urn study, carers stressed the significance of physical interaction as a way to bring objects to life and actively involve children. In all case studies, participants mentioned how experiences with replicas would motivate them to go to museums more often (61 out of the 83 participants in total), while some stated that they would go to museums anyway, but replicas would make visits more interesting. Another common aspect in all studies, was that people highlighted the benefits of replicas specifically for children and people with sight difficulties. Some considerations, though, emerged in the Picasso pot study, where few visitors expressed their concerns about the purpose of artwork if technology can perfectly replicate "unique" art pieces. Some also stressed that if replicas are exhibited, people should become aware of the fact that these are digitally fabricated objects and not originals.

8.2.2.4 Skills related implications

When it comes to skills, the act of exploring and interacting with the replicas was a process that involved the deployment of a many senses and a variety of skills. Many visually impaired users focused on tactile skills, while others (amongst this group) emphasised the combination of skills when exploring the relief. Fewer participants with sight impairment found it difficult to combine skills when exploring the relief. However, most of them felt confident to communicate their experience to others and part of those with partial sight felt connected to blind people's skills. Similarly, in the second case study, participants' comments evidence the use of tactile, intellectual, communication skills and their combination, but also reveal a connection to the skills of the artist who created the pot. In the puzzle-pot study, most carers highlighted the combination of skills to solve the puzzle, while also accentuating communication as part of the process.

8.2.2.5 Behavioural implications

The across-case behavioural examination demonstrates that replicas can change the way people access artefacts, by making experiences more "intense", by allowing visitors to bridge past with present, and by taking the "fear of engagement" away. In the study, with visually impaired users such changes acquire a further dimension, as people can overcome physical and geographical boundaries to experience history, art, natural specimens and generally

artefacts within the UK or abroad. Other behavioural aspects that were present in all case studies corroborate people's desire to see more digitally fabricated artefacts in the CH context. Hence, people discussed how replicas enabled them to feel part of the creation, discovery or exhibition of the artefact. They also mentioned that digitally fabricated artefacts could affect professional practices in the heritage sector. In addition, participants in all studies expressed a desire to progress and learn more or take actions as a result of experiencing the replicas, such as discussing the experience with others, finding out more about 3D printing or proposing a visit to the museum to relatives and friends.

8.2.2.6 Other experiential themes

In all case studies, a set of noteworthy themes have emerged from the analysis of data and were analysed separately in each case study. These are gathered in table 35.

Other themes			
General theme	**Kittiwake relief study**	**Pot Oiseau study**	**Puzzle-pot study**
Accuracy and authenticity	Realism Accuracy	Authenticity Accuracy	
Exhibition/experience practices	Guidance	Honesty	Interactivity Contextuality
Access	Portability		
Evaluation		Difficulty in rating	
Nature of replica	Fragile nature	Fragile object	

Table 35: Other themes resulting from the qualitative analysis.

By looking at these themes and consequently grouping those that seem relevant, five main strands emerge enabling the following general remarks:

Accuracy and authenticity: Realism, "accuracy" and authenticity have been topics brought out in different instances, when discussing about the experiences that audiences had with replicas. Visually impaired people appreciated the "accuracy" of the relief with regards to the representation of the kittiwake. Nonetheless, some would prefer a full 3D representation and more accurate solutions to represent natural materials. In the second study, random adult visitors positively commented how "identical" the replica was to the Picasso Pot Oiseau. It could be argued that accuracy affects authenticity. In reality though, it is *contextually informed relatedness* that appears to affect people's ideas about authenticity. For instance,

many people mentioned that they did not mind handling the Pot Oiseau replica, as it made them feel close to the original, its materials and creator. Thus, the possibility to tactically interact with a replica seems to add value to an experience that in this way becomes more "authentic". Counterarguments or considerations of course exist. These reflect certain scepticism (sometimes by people with CH background) about the "lack of human touch" and the fact that the spatiotemporal dimension of replicas could not be the same as that of the original artefacts.

Exhibition/experiences: Guidance, honesty, interactivity and contextuality are placed under this theme. Even though they have emerged from different case studies, they can benefit audiences in replicas' experiences. Pre-visit guidance and while exploring replicas are essential for the visually impaired. Informing all visitors, though, who encounter a replica that this can be touched/lifted/assembled is important too. This notion of guidance is also relevant to honesty and contextuality, as people need to know that these objects are replicas along with further contextual information. Interactivity, on the other hand, while being an essential element of all tactile experiences, appears as a significant aspect of the families' engagement with the puzzle-pot.

Access: Portability is placed under the theme of access, but guidance is relevant to this as well. With the kittiwake relief and application being portable, visually impaired users had the opportunity to experience a natural history exhibit that otherwise - due to lack of infrastructure and general provision- would be difficult to access. Certainly, there is still a need to promote noninstitutionalised experiences and facilitate access to heritage settings and exhibits for the visually impaired. Yet, providing interpretative means, such as replicas, can "break" physical and intellectual boundaries allowing people with visual impairment to enjoy artefacts in alternative ways.

Evaluation: This refers to a certain difficulty when rating some of the sensorial properties of the replicas; a remark more obvious in the Picasso pot study but existing up to a point in the other studies too. It seems that such difficulty is influenced by nonfamiliarity with the matter, as well as the presence of the original artefact and the possibility to conduct comparisons. A careful selection of properties along with clear guidance is helpful to resolve any misunderstandings and help people to rate.

Nature of replica: Replicas seem to have inherited the "fragile", "valuable", "no-touch" attributes of the originals they represent. This relation appears stronger when the replica resembles to the original. Thus, people become reluctant to touch because they are not used to touching objects in a heritage context or because they believe they might damage them.

8.2.2.7 Children's artefacts

Children's artefacts and statements on cards were used to gather information about their thoughts, ideas, potential reading of the exhibit, feelings and so on. Most children's artefacts depicted imaginary scenes, mixing fantasy with reality about the things they like, often inspired by their museum visit or historical knowledge. Another prominent theme were coloured blocks, resembling somehow the overall character of the puzzle activity. Fewer children directly "transferred" patterns and colours of the puzzle-pot into their artefacts. As far as it concerns their statements, the majority of children expressed their joy of creation and satisfaction with their decorated shard, while a considerable number of children made history and archaeology related comments. The overall thoughts and ideas that children drew and discussed evidence a wealth of engagements either with the puzzle-pot activity, topics related to history as triggered by the museum visit or even things they might enjoy in their daily lives.

8.3 Considerations and recommendations

8.3.1 The power of replicas

Through the analysis of findings and by looking at the across-case remarks, it could be conclusively claimed that *replicas add significant value at multiple perceptual levels* of the CH experience. As such, they *enable audiences to establish new relationships with the artefacts* and *develop a deeper understanding of the narratives around them*; something evidenced by the *wealth of engagements* and other *affective, learning, skills related, attitudinal and behavioural responses* of the examined audiences. Physical interaction with digitally fabricated artefacts is crucial in this sense, as it has the potential to *trigger a series of effects that bring original artefacts closer to people*.

This thesis bears testament of digitally fabricated replicas' function and significance as artefacts that *have an existence of their own which is profoundly interconnected to that of the originals*. In fact, replicas act like *"enriched mediators",* whose sensorial properties and role

as interpretative devices co-exist within highly contextual experiences. The potential of digitally fabricated artefacts, backed by the deployment of 3D technologies which in reality enable the production of "accurate", accessible, customisable and cost-effective replicas, is already strong. Such potential can be maximised through *careful design* and *honest representation*, while supporting and even *motivating visitors to participate* in the interpretation process. Hence, *audiences actively construct their own meanings* around artefacts and become the "authors" of experiences. Such capabilities, not only *deformalise the museum visit* and *democratise CH* (as each individual becomes a distinct authoritative voice), but also *"render" authenticity* in each CH experience.

In order to maximise these effects, stakeholders designing experiential frameworks that make use of digitally fabricated artefacts, need to take into account a series of recommendations and guidance that have derived from this research. These are presented next.

8.3.2 Recommendations

The remarks and recommendations below are experience and data driven. Hence, they derive both from the overall experience of the design and development of the research, as well as the evaluation findings. These remarks and recommendations have general applicability and should be taken into consideration, along with guidance on how to deploy the RXF (8.4.2), as they can significantly facilitate the whole lifecycle of replicas' experiential framework design, introduction, function and evaluation.

8.3.2.1 Planning and designing replicas

- The RXF can facilitate a number of decisions around the incorporation of replicas in experiences. Section 8.4.2.1 provides guidance on how to deploy the RXF when planning and designing replicas.
- A review of available literature and paradigms is useful in order to enable thinking around the incorporation of replicas (e.g. looking at audience classification can help with audience selection; looking at examples of replicas for disabled audiences or children can help with discussions around the nature of the replica and appropriate complementary media).
- Collaboration between various stakeholders (e.g. curators, designers, artists, technicians) is essential from the beginning of each project that involves a digitally

fabricated artefact, as it can bring out new considerations with regards to the production and integration of replicas in experiences.

- Resources (human, technology, budget) influence all decisions and should be taken into account from the beginning/planning phase of a project. For instance, a budget might determine that certain objects should be prioritised for fabrication; some technologies and materials might be cheaper than others; only limited number of people might be available to work on a project; an audience might be prioritised because there is available budget for specific purposes in a heritage organisation (e.g. setting up a new exhibition for young audiences influences the type, function and production of replicas) and so on.

8.3.2.2 Social aspect of engagement and interaction

- Visitors mostly experience replicas in company of other people. Design should facilitate the exploration by groups of people and be as inclusive as possible to avoid excluding other visitor groups.
- Heavy visitor flows affect the visibility of replicas and interaction with them. Careful design should anticipate and try to minimise negative effects from the presence of large numbers of visitors close to a replica, which will most probably constitute a point of attraction.
- When the target audience comprises people with impairment, careful design should facilitate independent exploration without preventing social interactions.
- Visitors' physical and verbal social interactions around the replica tend to be closer to narratives around the artefact itself and might be more imaginative, when the replica does not present a challenge or activity. Depending on the purpose of the replica, this should be taken into consideration at the planning/design phase.
- Visitors' physical and verbal social interactions around the replica concern more the actions they perform, when the replica presents an activity or task. Such engagement, though, often relates -amongst others- to feelings and expressions of joy and satisfaction. Depending on the purpose of the replica, this should be taken into consideration at the planning/design phase.

8.3.2.3 Physical aspect of engagement and interpretation

8.3.2.3.1 Replicas' location and setup

- Design of the physical setup of the replica should take into consideration the social aspect of replicas' exploration (explained above) as well as the nature of the exploration. Target and non-target groups' participation should be facilitated by following an as much as possible inclusive approach when setting up a replica (e.g. younger siblings wanting to assemble a puzzle should not be excluded).
- Replicas should be placed in obvious, not "hidden" parts of an exhibition, and -if possible- away from exhibition "exit points" and busy areas (in terms of busy interpretation/media offerings).
- Precise guidance, motivation to touch a replica or try an activity that includes a replica is also imperative, as most audiences are not accustomed to using other senses apart from sight in a museum context.
- When targeting visually impaired or other disabled audiences, alternative ways to present or transfer portable replicas is a solution that CH organisations should consider especially for those who might face accessibility difficulties.

8.3.2.3.2 Relation to original and interpretation

- Placing the replica close to its original artefact results in establishing clearer connections to it and triggers interesting dialogues.
- Replicas in close relation to the original and with honest representation do not distract users. In fact, replicas work best when they are collaboratively supported by other interpretative information.
- Replicas need an honest representation and audiences want to know what they are. Information about their materials and the digital fabrication method can be included when replicas are presented in an exhibition. Such information might result in further engagements. Being honest about the existence and purpose of the replica can overcome fear to touch and ethical considerations that might arise by its presence.
- A well-structured audio narration, designed with specific guidelines (see 5.3.3.2), is a vital element for any audio supported replica interpretation for people with visual impairment. Braille is useful, as well as other imaginative representations of elements (e.g. soundwave, organic materials to feel).

- Context-aware applications to complement experiences with replicas for people with visual impairment should be seamless and make use of functionalities that are designed for such users (e.g. voice reading and control).
- Guidance before and during the museum visit, as well as when interacting with replicas is paramount for visitors with disabilities. Overall accessibility infrastructure is significant for those groups.

8.3.2.3.3 Replicas' properties and feel

- Replicas' properties should be as close as possible to the properties of the original artefacts they represent, while being *contextually informed*. People tend to compare the properties of replicas to those of the originals. Yet, contextual parameters (e.g. target audience, location purpose, see 8.4.2.1), feasibility of production, availability of resources should be taken into consideration when designing a replica.
- Replicas should be made of durable materials that are as close as possible to the originals' materials and should be non-hazardous for the intended use.
- Replicas for people with sight loss, should abstract the main information/figures/forms of the original artefact. Textures should be close to the originals or other creative ways to experience textures can be deployed. Size of replicas, elevations and Braille should follow appropriate guidelines (see 5.3.3.1). Colours will not satisfy all users and alternative ways to represent colours (such as different coloured replicas or paper coloured depictions) could be considered for people with partial sight.

8.3.2.4 Expressive and perceptual aspects of engagement

- Replicas' potential with respect to the expressive outcome of audiences' experiences is maximised when these are supported by interpretation which enhances contextuality. Interpretation can include information about the nature of the replica, along with information about the original.
- Audience engagements become richer when multiple senses are involved in replicas' exploration. Replicas as interpretative means should enable people to use vision, touch and -depending on the exhibit- hearing and taste.

- When targeting audiences that include children, a physical-intellectual challenge or hands-on activity with replicas can benefit them at multiple levels, including learning, skills acquisition, interest enhancement and enjoyment.
- Audiences desire more replicas, as these deformalise the CH experience. CH organisations should consider replicas as part of their accessibility, equality and audience development plans.

8.3.2.5 Evaluating replicas in the heritage context

- The RXF and the methods deployed in this research can facilitate the evaluation of digitally fabricated artefacts within CH experiences. Section 8.4.2.2 provides guidance on how to perform evaluation while deploying the RXF for this purpose.
- Every evaluation effort should be carefully planned while taking into account the available resources (e.g. researchers, available time, tools, analysis skills etc).
- Replicas' evaluation should be piloted within realistic contexts (if possible), as trialling will most probably reveal aspects that need to be taken into consideration for the overall evaluation of the replica experience.
- Creative (e.g. artefacts and graffiti wall cards) and/or participatory methods to evaluate audience's experiences with digitally fabricated artefacts can be also developed by researchers and heritage organisations.
- The deployment of appropriate methods to evaluate replica experiences involving the use of IT with visually impaired audiences is an open field of exploration. The "open-ended" character of a smart replica experience might not always be compatible with task-oriented methods.

8.4 Revisiting the Replica Experience Framework

8.4.1 The value of the RXF

The *Replica Experience Framework (RXF)* constitutes a valuable theory and evidence driven addition to a growing body of research about digitally fabricated artefacts in CH experiences. Its value lies in its multifaceted accomplishment:

- To *document* the production, type and function of digitally fabricated artefacts within CH experiences (Chapter 4, Appendix A); something that enhances the study

around replicas and could lead to further developing metadata records in IT systems to document replicas, including information on audiences' experience of them;

- To *decode* the role of replicas by "breaking down" experiences and hence demonstrating the key *points* for evaluation; the classification of the RXF (Appendix A) as well as its investigation aspects (reference table in same appendix) and guidance, as presented in 8.4.2.2, can be particularly helpful to guide evaluation;
- To *support* stakeholders about the decisions that need to be taken for the production and integration of replicas for interpretation; something facilitated by looking at all the experiential aspects of the RXF (Appendix A reference table) and making the appropriate decisions that will also correspond to the purpose of the replica and its audience (see guidance in 8.4.2.1);
- To potentially *assist* efforts for the standardisation of replicas within the heritage context and the development of intelligent systems to support replicas' production and integration; standardisation efforts, similar to the *London Charter* (Denard, 2012; 2009), refer to the provision of guidance and standards for the products of heritage digital fabrication; while the development of intelligent systems refers to successfully defining replica's properties for a given purpose, context and audience with the deployment of AI (this would require a large amount of data to train such system).

The RXF, as the starting point of this research, "was built" inductively by combining theory, methods and information deriving from a variety of events, training, discussions in the heritage and digital humanities domain. The structure of the RXF informed the choice of appropriate data collection methods and guided the analysis of the research findings in a mixed approach (primarily deductively, while inductively allowing themes to emerge). All research findings have been presented under the personal, social, physical context classification, as well as the expression-perception of the experience, as defined by the RXF. A set of particularly interesting themes that have emerged through the analysis have been also presented separately, as they deserve particular attention. It is necessary to stress that all these themes have originated from the evaluation as designed based on the RXF classification and the deployed methods, however they might have been implied in multiple categories in the data analysis (e.g. *portability* originated from comments about the property of *weight* of the kittiwake relief as well as *behaviour* related comments); their significance is

particularly evident throughout the case study (*interactivity* and *contextuality* emerging from many themes in the Saltdean puzzle-pot study); they might reveal more abstract notions of the replica experiences (*authenticity* as an important theme); or even originate from methodological aspects of the experience evaluation (e.g. *difficulty in rating* some sensorial properties). Hence, a conscious decision was made to further present these themes separately and emphasize their importance.

Taking under consideration that the RXF has served well the purpose of information collection, classification and analysis, while allowing for significant themes to emerge, further modifications in the context of this research do not appear to be needed (might be needed though to support other research goals).

8.4.2 Deploying the RXF

8.4.2.1 The RXF to design replicas

The RXF, as already stated in 8.3.2.1, can be deployed during the process of planning and developing/designing digitally fabricated artefacts for heritage interpretation -similarly to exhibition design (Dean, 1996, pp. 8–18; Locker, 2011, p. 36)- in order to facilitate professionals to make a number of decisions. During the planning process, a wealth of input, as well as the involvement of various stakeholders, enabled to form the initial concept for each replica experience. Likewise, during the development/design process, key aspects of each experience were further elaborated in order to produce the final digitally fabricated artefact and complementary interpretative material. Consideration of available means and resources also ensured the feasibility of plans.

To conclude, interdisciplinary collaboration, examination of relevant examples and availability of resources should always be taken into account, when designing experiential frameworks that include a digitally fabricated artefact. Then, professionals can also look at the RXF in order to make a number of decisions as described below:

Planning for the incorporation of a replica (general concept)

- Audience investigation: by looking at the *Personal context* of the RXF, professionals can develop their thinking about the replica's potential audience. *Social context* consideration can further help to think about the composition of such audience (and possible interactions).

- Object investigation: by looking at the *Physical context* of the RXF, object selection (*CH object* in the RXF) can be facilitated. Considering which original object to replicate will also depend on space arrangements (*Space*) as well as the existence of other interpretative media (*Interpretative/Supportive material*) and audience investigation as presented above.
- Replica investigation: by looking at the *Digitally fabricated artefact* along with the *Expression - Perception* aspect and the *Context* of the RXF, stakeholders can think of potential desired outcomes of the experience and what implications could these have (e.g. a portable replica for blind audiences, a puzzle replica for children).
- Interpretative media investigation: by looking at the *Interpretative/Supportive material, the Media* (images, videos etc) to complement the *Digitally fabricated artefact* can be considered as well as its *Function*, such as the potential to include some interactivity (e.g. audio for the blind people, written guidance to people to touch the Picasso pot).

Actual examples of planning -hence considering the above topics- for the incorporation of a replica within a CH experience can be found in sections 5.2, 6.2, 7.2 of this thesis.

<u>Developing/designing for the incorporation of a replica</u>

- Audience specification: by looking at the *Personal* and *Social context* of the RXF, professionals can decide on the characteristics of audience for the replica experience. Visitor classification (2.6) can further systematise such decisions.
- Object specification: by looking at the *CH object* (original artefact) as well as the *Space* (within an exhibition/setting) and *Interpretative/Supportive material* in the RXF along with audience specification (see above), decisions about the selection of replicas can be made (e.g. flagship gallery includes the Pot Oiseau which attracts many visitors, Booth museum showcases dioramas which cannot be accessed by any other means by visually impaired people).
- Design of replica: by looking at the *Digitally fabricated artefact* in conjunction with the *Context* and *Expression-Perception* (desired outcomes), decisions can be made about the *Function, Type (sensorial properties)* and *Production processes* for the replica (e.g. puzzle activity for children of a certain age results in specific size for puzzle pieces that will require certain *3D processing, joining* and *surface treatment*).

- Design of interpretative media: by looking at the *Interpretative/Supportive material*, the *Media* (images, videos etc) to complement the *Digitally fabricated artefact* can be decided along with details about their *Function* as independent supportive material or as part of an *Interactive* (smart) *object* (e.g. audio for visually impaired structured in certain ways with hands-free initiation).

Actual examples of developing and designing a replica within a heritage experience can be found in sections 5.3, 6.3 and 7.3 of this thesis. Lastly, is should be stressed that the deployment of the RXF complies with a variety of design and co-design approaches, as presented for instance in Avram and Maye (2016). This happens because in reality the RXF points to the main "ingredients" of an experience and hence it can constitute a valuable reference map during the planning and design process.

8.4.2.2 The RXF to evaluate replicas

This thesis demonstrated how the RXF can be deployed to evaluate replicas in experiential frameworks. Thus, it can constitute a good example to guide similar research and evaluation efforts that revolve around replicas.

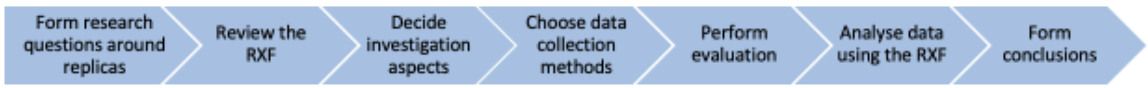


Figure 104: Deploying the RXF for evaluation purposes.

In order to employ the RXF to evaluate digitally fabricated artefacts within CH experiences, researchers and stakeholders could follow a process as presented in fig. 104. Hence, they could start by looking carefully at their research questions. Next, they could review the RXF in order to see whether its experiential topics can respond to the research questions (Appendix A). Depending on the type of queries, further topics could be implemented into the existing framework or some topics can be examined separately. When deploying the RXF, it is important to remember that its structure does not need to be rigidly adopted. Instead the RXF can adapt or expand to provide space for other experiential elements, based on a given project, complementary media and overall research questions. An example could be the deployment of replicas as physical interfaces to facilitate navigation and interaction in a Virtual Reality (VR) environment (Gaugne et al., 2018). In such case, more categories/data under the concept of *interactive object (smart)* in the RXF could look at topics related for

instance to the *user's presence* in the VR environment (e.g. sense of physical space, ecological validity, negative effects and more) (Lessiter et al., 2018).

As soon as the RXF review has been completed, the reference table in Appendix A can provide inspiration to form questions around the investigation aspects of the RXF. Then, the appropriate methods to collect evidence should be decided, based on several criteria such as: the need to collect data of quantitative and/or qualitative type; the type of data analysis; the available resources in terms of time, participants and evaluators; and data triangulation. In museum studies and audience research literature, several methods to collect data can be found. Every method has its strengths and weaknesses, and all are further influenced by the availability of resources. For instance, Nelson (2015) and Diamond (2016) provide a nice overview of methods that can be used to evaluate CH programmes and activities. Observations, surveys and interviews are amongst the ones widely utilised in CH contexts. Similarly to the current research, both quantitative and qualitative methods can be used. Starting from the RXF, contextual information relating to the personal context can be recorded through questionnaires. Data around the social context and parts of the physical context can be collected through observations while participants interact with replicas. On the other hand, data about the subjective sensorial properties of the replicas can be measured quantitatively on a satisfaction rating scale or with open-ended questions, if that better suits the purposes of a research. When rating the sensorial properties of replicas, the examined properties should be carefully chosen based on the RXF. Only the properties that correspond to the type of object and target audience should be examined (e.g. visual properties would not be appropriate for blind audiences) and further explanations should be given for properties that people might not be familiar with. Lastly, the overall expression of the experience in terms of awareness/knowledge, engagement/interest, attitudes, behaviours and skills can be better explored through qualitative means, such as focus groups or interviews, in order to detail the wide range of people's opinions and impressions. The above suggestions do not imply that certain methods should be used strictly, but rather creatively, based on the scope and resources of every project.

Then, evaluation needs to be piloted, in order to identify issues that might need to be addressed before the bulk collection of data. As soon as the evaluation has been completed, data will have to be analysed. The RXF as well as this thesis provide a useful example to

demonstrate how quantitative data can be analysed with descriptive statistics and qualitative data by following a mixed approach, while deploying the RXF themes for the presentation of findings. Conclusions can then be made after examining the analysis of evidence.

8.5 Research aim, questions and objectives

The aim of this research was to identify the properties of digitally fabricated artefacts and investigate their dynamics, in order to provide a framework that can support decisions and practices when introducing replicas in CH experiences for different audience groups. This aim has been achieved by following a step-by-step approach to fulfil the objectives of the research in order to respond to the research questions. Table 36 presents where the RQ and related objectives have been addressed within the thesis.

RQ1: What are the possible intrinsic and extrinsic properties of digitally fabricated artefacts?	
Objectives	**References**
OB1: To investigate the intrinsic and extrinsic properties of digitally fabricated artefacts and study issues which are related to their production, materiality, tactile appreciation and overall experience of the object.	Chapter 2, Chapter 4
RQ2: In which ways do the properties of digitally fabricated artefacts address the requirements of different audience groups?	
OB2: To identify different cultural heritage audiences, select appropriate representative groups for the purposes of this research and consider their expectations and requirements from digitally fabricated artefacts.	2.6, 3.4.9, Chapter 5, Chapter 6, Chapter 7
OB3: To examine the properties of digitally fabricated artefacts with respect to different audience requirements through evaluation within interpretative contexts.	Chapter 5, Chapter 6, Chapter 7, 8.2.1.3.4
RQ3: How do digitally fabricated artefacts work in CH experiences for different audience groups?	
OB4: To investigate how digitally fabricated artefacts work within cultural heritage experiences and propose ways for their successful integration in real life scenarios.	Chapter 5, Chapter 6, Chapter 7, Chapter 8
RQ4: How can we describe digitally fabricated artefacts in a conceptual model that both documents them and decodes their role within cultural heritage experiences?	
OB5: To conceptually describe digitally fabricated artefacts to document the transition from the digital object to its physical manifestation (fabricated product) in ways that can support several CH management processes (e.g. production processes to support documentation) while focusing on communication.	Chapter 4, Fig. 13, RXF in Appendix A, reference table in same appendix

Table 36: Research questions responded through the specific objectives with references in this thesis.

To summarise, the research questions have been responded as explained below:

RQ1: A large part of the literature review in Chapter 2 has been dedicated to studying the significance and novelty of digitally fabricated objects as a recent technological advancement; the methods that have been developed for the production of replicas; the importance of their material aspect with respect to tactile appreciation; as well as information on authenticity. Moreover, replicas' deployment for a variety of communicative purposes in the CH context was examined. Then, the principles which guided the development of the RXF theoretical proposition were described in Chapter 4, in order to define the *intrinsic* and *extrinsic* properties of replicas. The first ones are the *internal properties* of the fabricated artefacts. They consist of *physical properties* which are translated into *subjective sensorial properties*. The extrinsic properties of replicas are the *relational, semantic or expressive* properties of the fabricated artefacts, reflected through skills, knowledge, attitudes, values, behaviours and interests as examined in the RXF.

RQ2: Different cultural heritage audiences' classification schemes have been presented by looking at the CH literature and visitor research in 2.6. The *target audience* approach was then selected for this research and justification for the selection of the specific case studies' audiences followed firstly in 3.4.9 and then separately within each case study chapter (Chapters 5, 6, 7). Requirements for the production of replicas, limitations, guidelines, and all related considerations have been then described in the development and design section of each case study (Chapters 5, 6, 7), along with information about the production of interpretative material, such as the video for Pot Oiseau and the audio context-aware application for the visually impaired. How replicas' properties work for each audience (i.e. evaluation of the properties) was analysed in the findings of each case study chapter (Chapters 5, 6, 7). Across-case examination has been also performed and audiences' preferences were translated into requirements in 8.2.1.3.4 per case, while allowing for some common tendencies to emerge. The replicas' requirements in each case can have applicability in scenarios where similar audiences are targeted, and similar artefacts are digitised and fabricated. Tendencies though, as presented in 8.2.1.3.4, can have general applicability when a digitally fabricated replica is used for interpretation. Hence, these tendencies have been translated into recommendations as explained in the following RQ3.

RQ3: The way that digitally fabricated artefacts work within each cultural heritage experiential framework has been detailed per case study by looking at the contextual and expressive findings of each experience (Chapters 5, 6, 7). Across-case examination and reflection on how replicas worked has been also presented in Chapter 8. The same chapter includes conclusive information on the significance and value of replicas, along with guidance and recommendations to assist those who are interested in integrating replicas in heritage interpretation. These can have general applicability too.

RQ4: The RXF, as the theoretical proposition of this research has been detailed in Chapter 4. Digitally fabricated artefacts, as well as every other "ingredient" of the cultural heritage experience with the involvement of a replica has been analysed there. The RXF concept can serve the study and documentation of replicas (through functional, sensorial and production properties; the later describing the transition from digital to physical) and "decodes" their role within highly contextual experiences. A summary of the RXF concept map is visualised in fig. 13 and the full version is presented in Appendix A along with a reference table analysing the RXF classification and investigation aspects.

8.6 Contributions

The contribution of this thesis is multi-fold and can be described in terms of various perspectives.

From the *theoretical and methodological perspective*, the thesis delivers:

- A theoretical framework serving the study and documentation of replicas as it structures knowledge around them and "decodes" their role in CH experiences. (Chapter 4).
- A well-rounded set of methods for the systematic and holistic evaluation of digitally fabricated artefacts within interpretation frameworks. The proposed methods not only analyse and record the impression of the experience (qualitatively) but also examine the properties of replicas (quantitatively) in a systematic, reusable and expandable way (Chapter 3, Appendix A and reference table in the same appendix). Actual examples of the deployment of these methods can be found in the case studies of the research.

From the *visitor research perspective*, the thesis contributes to an:

- Increased understanding about the way that audiences perceive, interact with, and experience digitally fabricated artefacts within interpretative scenarios. The research provides information with regards to three realistic case studies where replicas were used to support artefact interpretation for different audiences (Chapters 5, 6, 7, 8).

From the *curatorial and design perspective*, the thesis proposes:

- A comprehensive framework that can be deployed to guide decisions (Chapter 4, 8.4.2) along with a set of recommendations (8.3.2) for planning, designing and effectively integrating digitally fabricated artefacts to support interpretation. Researchers, curators and other stakeholders can thus be informed and guided when making a number of decisions with respect to the introduction of replicas in exhibition settings, programmes and events. Such guidance can further work as motivation to explore the potential of 3D replicas to reach wider audiences and promote an accessible as well as inclusive profile for their organisation.

From the *IT and digital fabrication perspective*, the thesis provides:

- A framework and recommendations that can potentially assist efforts for the introduction of standards about the deployment of replicas for communication purposes in the heritage context (Chapter 4, 8.3, 8.4). Such standards or initiatives already exist for computer-based visualisation (see 8.4.1) and can be further extended to cover digitally fabricated heritage assets.
- Revelation of certain computer graphics and digital fabrication drawbacks to address audiences' requirements from replicas (5.5.3, 7.5.3, 5.5.4.6, 8.2.1.3.4). The research comprises evidence to support technological advancements in specific fields (e.g. automated/semi-automated methods to extract shape from image and elaborate abstraction, natural-like materials in fabrication).
- A valuable framework/concept that could be deployed to develop intelligent systems to assist curatorial decisions with regards to replicas. The RXF (Chapter 4) could guide this advancement, provided that a big amount of data could be fed into such system.

8.7 Further work

This thesis investigated the role and contribution of digitally fabricated artefacts within CH experiences. While the proposed RXF concept proved valuable to guide the design and evaluation of such experiential frameworks, more research could be undertaken to enrich the available data. In future, more case studies could be designed, and replicas examined in order to expand the investigation towards other audience groups and different types of fabricated artefacts. More young audiences, people with different kinds of impairment, people with mental health issues, people with chronic illness, hospitalised people, artists, museum professionals, elder people are some of the groups whose feedback would contribute into broadening our understanding about replicas. It would also be interesting to examine other artefacts from archaeological, fine art, ethnographic, natural history collections, including large-scale fabricated ensembles (moveable or not), so as to understand what the limitations are, the possibilities and audience's impressions when encountering such replicas.

From the methodological point of view, exploring participatory methods to design digitally fabricated artefacts and experiential frameworks with different target audiences, would be another interesting approach. Yet, such effort would also need to employ solutions to overcome skills and knowledge barriers with regards to the use of technology for imaging and fabrication. Similarly, open methodological questions remain on how to further progress research on the evaluation of context-aware, IT enriched, "living-experiences" with replicas, particularly with visually impaired users without deploying task-like activities.

From the IT perspective, developing intelligent systems to assist curatorial decisions about the design and incorporation of replicas in CH experiences would be another stimulating topic of research. The RXF could guide such technological advancement, provided that a big amount of feedback and contextual data about replicas' experiences could be fed into such system. In the graphics domain, a rigorous subject of investigation refers to the extraction of shape from 2D images. Elaborating and employing automated or semi-automated methods not only to extract shape from image, but also to apply a level of abstraction and produce representations that would be appropriate for the visually impaired is another topic that needs further investigation.

Lastly, as far as it concerns digital fabrication, some of the issues that need further research concern the development of satisfactory solutions for the representation of natural-like materials and the possibility to 3D print durable ceramics in colour.

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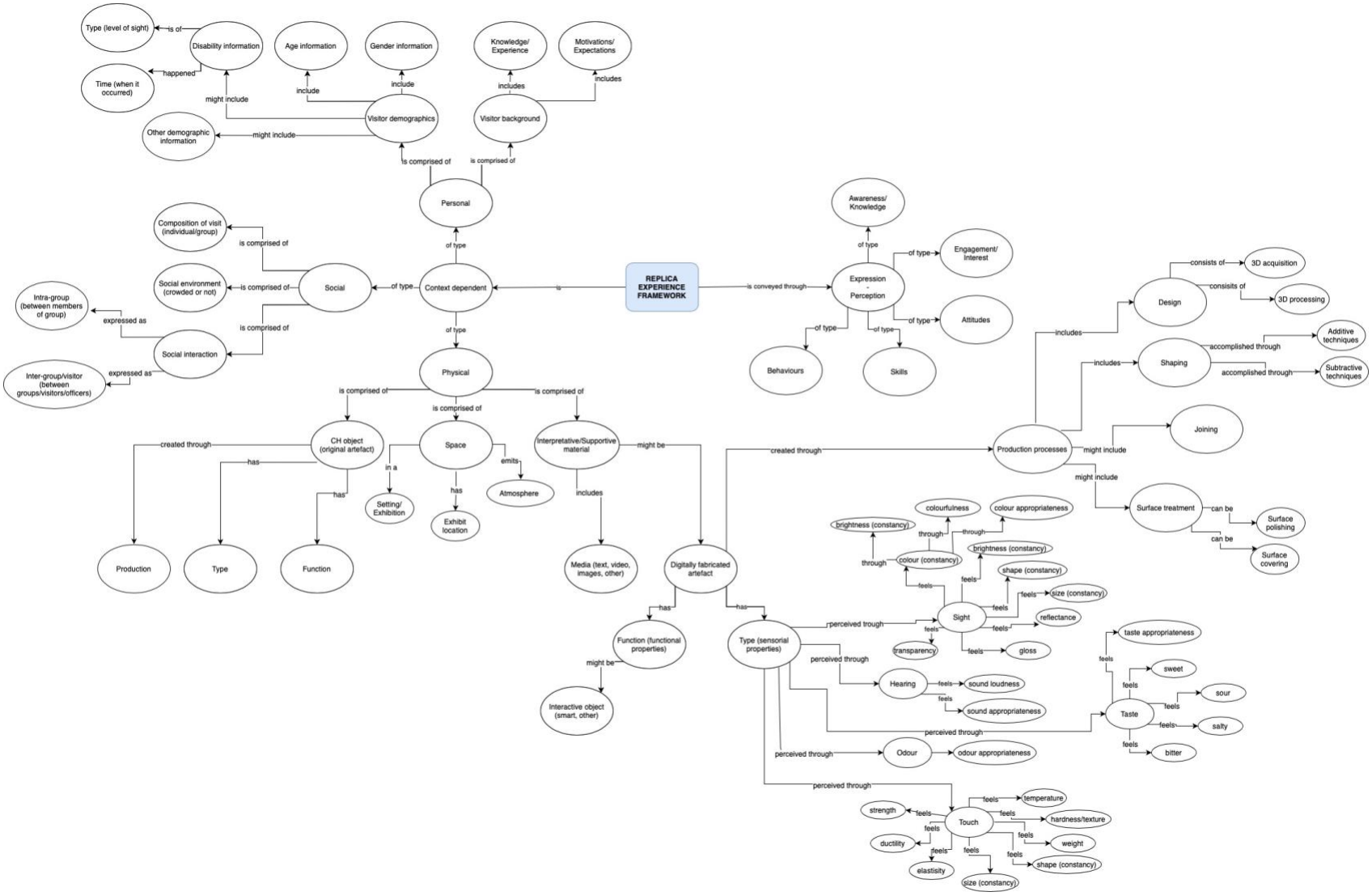
Appendix A: The Replica Experience Framework



Reference table of the Replica Experience Framework (RXF)

Replica Experience Framework			
Classification of experiential topics			*Experiential topics' investigation aspects*
Context			
Personal context			
Visitor background	Knowledge/Experience		- Experience of CH objects - IT experience - Relevant profession/other background - Previous visits - Education - Other (e.g. knowledge of topic, knowledge of Braille)
	Motivations/Expectations		- Expectations from visit - Plans for the visit - Specific interests (e.g. collections)
Visitor demographics	Gender information		- Visitor gender
	Age information		- Visitor age
	Disability information	Type of impairment	- What is the impairment (if applicable)
		Time	- When the impairment happened (if applicable)
	Other demographics		- Place of residence, ethnicity, income etc
Social context			
Composition of visit			- Sole visitor or part of group - Organisational structure of group - Who is in charge (if applicable)
Social environment			- Presence of other people

Replica Experience Framework					
Classification of experiential topics					*Experiential topics' investigation aspects*
					- Crowded or not
Social interaction	Intra-group				- Verbal interactions (within a group) - Physical interactions (within a group)
	Inter-group/visitor				- Verbal interactions (between groups) - Physical interactions (between groups)
Physical context					
CH object (original artefact)	Production				- Examined through the contextual and perceptual aspects
	Type				
	Function				
Space	Setting/Exhibition				- Museum, institute, open space etc - Exhibition room, gallery (big, small, traditional, novel etc)
	Exhibit location				- Where the exhibit is placed (near entrance, exit etc) - Arrangement in space (distribution within space, orientation etc)
	Atmosphere				- Feeling of space (light, noise, narrow, dark etc) - Ease of finding the replica - Attraction to replica
Interpretative/ Supportive material	Media (text, video, images, other)				- Satisfaction from media quality - Attraction to media - Ease of use
	Digitally fabricated artefact	Production processes	Design	3D acquisition	- Visitor satisfaction and comments about the sensorial properties which affect
				3D processing	
			Shaping	Additive techniques	

Replica Experience Framework						
Classification of experiential topics						*Experiential topics' investigation aspects*
				Subtractive techniques		production processes (e.g. gloss of replica and surface polishing/covering)
			Joining			
			Surface treatment	Surface polishing		
				Surface covering		
		Function	Interactive object (smart, other)			- Ease of use of interactive replica - Satisfaction from interactive replica
		Type (sensorial properties)	Touch	Temperature		- Subjective visitor satisfaction
				Hardness/Texture		
				Weight		
				Shape (constancy)		
				Size (constancy)		
				Elasticity		
				Ductility		
				Strength		
			Odour/Olfaction	Odour appropriateness		
			Taste	Taste appropriateness		
				Sweet		
				Sour		
				Salty		
				Bitter		
			Sight/Vision	Colour (constancy)	Brightness (constancy)	
					Colourfulness	
					Colour appropriateness	

<table>
<tr><th colspan="6">Replica Experience Framework</th></tr>
<tr><td colspan="5">Classification of experiential topics</td><td>Experiential topics' investigation aspects</td></tr>
<tr><td rowspan="8"></td><td rowspan="8"></td><td rowspan="8"></td><td rowspan="6"></td><td>Brightness (constancy)</td><td rowspan="8"></td></tr>
<tr><td>Shape (constancy)</td></tr>
<tr><td>Size (constancy)</td></tr>
<tr><td>Reflectance</td></tr>
<tr><td>Gloss</td></tr>
<tr><td>Transparency</td></tr>
<tr><td rowspan="2">Hearing/Audition</td><td>Sound loudness</td></tr>
<tr><td>Sound appropriateness</td></tr>
<tr><td colspan="6">Expression - Perception</td></tr>
<tr><td colspan="5">Awareness/Knowledge</td><td>- Acquisition of knowledge
- Broadening understanding
- Making sense of something
- Developing awareness
- Learning facts
- Connecting information (e.g. using previous knowledge)</td></tr>
<tr><td colspan="5">Engagement/Interest</td><td>- Using senses
- Evoked emotions
- Interest and engagement
- Exploration, curiosity
- Enjoyment, fun and surprise
- Creativity and inspiration
- Imagination
- Memory recall/connection to past</td></tr>
<tr><td colspan="5">Attitudes</td><td>- Values, beliefs, opinions
- Self-esteem, self-confidence</td></tr>
</table>

Replica Experience Framework	
Classification of experiential topics	*Experiential topics' investigation aspects*
	- Attitudes towards others - Ethical considerations - Attitudes towards organisations
Skills	- Acquisition/strengthening/deployment of skills (communication, creative thinking, problem solving, physical skills and more) - Connection to other people's skills
Behaviours	- Changes in people's lives - Progress - Future actions and developments - Changes in accessing information and organisations - Changes in practices

Appendix B: Case study 1 - guidance, protocols, data samples

Guidance sheet - Kittiwake relief study

Introduction & guidance

1. You are about to test a 3D printed relief and application that has been created to assist visually impaired audiences to access and explore the exhibits of the Booth Museum in Brighton.

2. We will ask you to carry a mobile phone with an audio description to help you with your exploration. You don't need to install anything on the mobile phone as the audio-application has already been installed and activated for you.

3. One of the "environmental displays" that belongs to the Booth museum is placed on a table in this room. In front of the diorama there is a 3D printed relief representing the contents of the display.

4. We will ask you to approach the table and sit on a chair. There you can explore the relief with your touch while listening to the audio description.

5. Please bear in mind that there is an option to control the audio playback by using the buttons of the application screen on the mobile phone. If you are familiar with the use of a smartphone please try it yourself. Otherwise you can ask a volunteer/helper or the researcher to help you, in case you want to pause, stop or restart the audio.

6. After your exploration, you will be asked about your experience with the relief and audio.

Interview sheet - Kittiwake relief study

Interviewer: Date: Location: Participant:

Questions

1. What do you think about the experience of exploring the relief with the help of the mobile device and the audio today? *(General intro question)*

2. Did the relief and audio help you to discover more information about the exhibit of the kittiwake? How? *(Awareness/knowledge question)*

3. Did you particularly enjoy anything about the experience with the relief today? (*Engagement/interest question)*

4. What do you think that is the value of having 3D printed objects available to the visually impaired and blind visitors of the museum? *(Attitudes/values question)*

5. Would similar experiences with the provision of 3D printed objects and audio change your opinion about accessibility to museums? (*Attitudes question)*

6. Would you talk to others about the experience that you had here today with the 3D printed relief of the display? *(Behaviours & Skills question)*

7. Is there anything else that you would like to comment on or share your thoughts about? *(General ending question)*

Observation sheet - Kittiwake relief study

Observer: Date: Location: Time in/out:

Personal context

Participant:

Gender (circle one): Female Male Other

Age (approximately, circle one): 18-24 25-39 40-49 50-59 60 plus

Social context

Composition of visit (circle one): Individual Group

If a group: How many people are they? Is someone in charge? Who?

Social environment (circle one): Crowded Not crowded

Social interaction:

Inside the group or between different groups/individuals/officers?	Who talks to whom	When does this happen	What do they talk about or need?	How (talk, look, are physical?)

Physical context

Describe atmosphere (Dark? Smelly? Narrow? Noisy? Soft/hard floor? Low/high display?)

Do people find the exhibit easily (without help)? YES NO

Comments:

Are they attracted by the replica? YES NO

Do they pay attention/read the Braille? YES NO

Define (if possible):

Do they pay attention to the audio and/or image in the app and/or physical object? Do they quit? Describe:
Is it easy to get the relief and associated application working and controlling it? Are there any problems? (usability) Describe:

Other comments/suggestions (notes):

Questionnaire sheet - Kittiwake relief study

General comments

Do you have any comments about the contents of the relief (e.g. scene, Braille label and sound wave on top)?

If you have partial sight, do you have any comments about the visual appearance of the relief (e.g. colour, glossiness, contrast, reflectance, brightness, transparency)?

Object features and mobile application

How well do you think that this relief works for people like you? On a rating scale from 1 to 5 how satisfied are you with the following features of the relief?

Size

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

Shape

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

Weight

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

Texture

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

Temperature

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

Durability *(whether the material is strong)*

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

If you are not satisfied with any of the relief's features, please tell us how would you like it to be.

On a rating scale from 1 to 5 how easy or difficult was it to use the mobile application?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very difficult	Difficult	Neither	Easy	Very easy

On a rating scale from 1 to 5 how satisfied are you with the audio description of the relief?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

Visitor Background

Are you a Braille reader? ☐ YES ☐ NO

Have you ever visited the Booth museum?

☐ YES ☐ NO

Is your current/past occupation/s related to the cultural heritage sector (museums, archives, libraries, arts, humanities)?

☐ YES ☐ NO If yes, please specify:

How often have you been provided with museum objects to touch before?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Never	Rarely	Sometimes	Often	Always

Have you used technology as part of a museum experience before?

☐ YES ☐ NO

What did you expect to do or explore during your visit/this event today?

Are you interested in specific collections/objects of the Booth museum?

Visitor Information

To which gender group do you belong?

☐ Male ☐ Female ☐ Other

What is your age group?

☐ 18-24 ☐ 25-39 ☐ 40-49
☐ 50-59 ☐ 60 plus

What is your ethnic group?

☐ White ☐ Mixed/Multiple ethnic groups ☐ Asian/Asian British
☐ Black/African/Caribbean/Black British ☐ Other ethnic group

Approximately how many miles away do you live from the museum?

What is your level of sight?

☐ Blind ☐ Partially sighted ☐ Sighted blindfolded

If you are blind, do you mind specifying if you have any visual memory?

Thank you very much.

Audio description - Kittiwake relief study

Display - general introduction (general view/representation)

You are approaching a glass display or a Victorian 'environmental diorama' - as it is called - showcasing a stuffed kittiwake standing on a rock and gazing across the horizon.

Relief - general introduction (general view/representation + location of each element)

In front of you on the table there is a simplified version of the contents of the display in the form of a raised-relief. Let's start with a general explanation about the scene and then proceed to the exploration of its individual parts. Please follow with your hands at the pace of the narration as the description continues.

Now place your hands on the relief. From top to bottom, the relief features:

- first a series of disks that represent the soundwave of the kittiwake's call;
- right underneath there is the raised figure of an adult seabird, a kittiwake, mounted on a rock and presented in a profile view, with its head looking to the right;
- on the left side of the bird, above its wings and body, there is a label in Braille with the word "kittiwake";
- right under the kittiwake at the bottom of its legs there is the rock where the bird stands;
- on the surface of the rock there are some raised areas representing sea plants and a ball of whelk eggs;
- lastly, at the very bottom of the rock there is the bumpy area of the ground that expands across the relief.

Relief - in detail (description in detail: position, direction, materials, colours)

Let's now describe each separate element of the scene. Please follow with your hands as the narration evolves.

Start again from the top of the relief. At the very top, you will find a raised representation of the soundwave produced by the kittiwake's call. The loudest parts of its call are represented with high-raised disks whereas the softer parts have lower heights and are smaller.

This is how it sounds *(sound of the bird's call).*

Let's continue with the exploration of the kittiwake which is the central and tallest figure of the relief. At the very top of the figure, is the head of the bird. There you will find its round

eye. Further to the right, you will also discover the bird's small pointed bill. Kittiwakes have yellow bills, which help them to catch shrimps, worms and small fish.

Moving your hands lower and closer to the body of the bird you will feel its raised wings. The body and the head of the kittiwake are both white and its wings are mostly grey with black-tipped feathers. Right under the body, you will discover the bird's legs which are short and its feet which touch the surface of the rock. Kittiwakes' legs can be black or red. This is a black-legged kittiwake. The size of the adult bird in the glass display is approximately 30-40 cm in length, from bill to tail. This bird would normally have a wingspan of 90 cm.

Now proceed to the exploration of the rock. Follow with your hands the raised contour of the rock right under the kittiwake's legs. In the glass display, this rock is made of papier mache and has been painted in grey to resemble a real rock. On the surface of the rock, close to its centre and slightly to the left, you will discover an irregular shaped object. It represents a mass of beige seaweeds that were washed up or left to dry on the rock. On the left bottom part of the rock there is also another irregular mass of brown seaweeds.

Now follow again the contour of the rock towards its right bottom part. There, you will feel an almost oval-shaped raised ball of whelk eggs. In the glass display this has a soft beige colour. If you place your hands at the very bottom of the relief, right under the rock and the seaweeds, you will find the bumpy area of the ground that expands across the relief. The ground in the glass display consists of small pebbles and gravel which are brown in colour.

Kittiwake - general information (summary)

Let's now find out some more details about kittiwakes. Kittiwakes belong to the gull family and can be found in large coastal colonies around the UK. In summer the species breeds in the North Pacific, North Atlantic, and in the Arctic oceans. In winter, kittiwakes spend most of their time out at sea. Kittiwakes are a cliff-nesting gull species, but occasionally use man-made structures. Their name derives from their call *(sound of the bird's call).*

Guidance sheet in Greek / Φύλλο οδηγιών – Ανάγλυφο ρίσσας

Εισαγωγή και Οδηγίες

1. Πρόκειται να εξετάσετε ένα τρισδιάστατα εκτυπωμένο ανάγλυφο και μια συνοδευτική ηχητική εφαρμογή κινητού τηλεφώνου. Το ανάγλυφο και η εφαρμογή δημιουργήθηκαν για να υποστηρίξουν χρήστες με μειωμένη όραση και μη βλέποντες στο να περιηγηθούν σε εκθέματα του Μουσείου Φυσικής Ιστορίας Booth του Μπράιτον της Μεγάλης Βρετανίας.

2. Θα σας ζητήσουμε να φορέσετε στο λαιμό σας μια θήκη με ένα κινητό τηλέφωνο στο οποίο έχουμε εγκαταστήσει μια ηχητική εφαρμογή που θα σας βοηθήσει στην περιήγησή σας στο ανάγλυφο. Δεν χρειάζεται να εγκαταστήσετε τίποτα στο κινητό τηλέφωνο. Η εφαρμογή έχει ήδη εγκατασταθεί και ενεργοποιηθεί για σας.

3. Μία αφίσα με εκτυπωμένη την εικόνα της προθήκης από το Μουσείο Φυσικής Ιστορίας Booth έχει τοποθετηθεί απέναντί σας. Μπροστά από την εικόνα και πάνω στο τραπέζι βρίσκεται το ανάγλυφο που αναπαριστά το περιεχόμενο της προθήκης.

4. Θα σας ζητήσουμε να πλησιάσετε το τραπέζι και να καθίσετε στην καρέκλα. Εκεί μπορείτε να εξερευνήσετε το ανάγλυφο με την αφή, καθώς ακούτε την ηχητική περιγραφή.

5. Θα θέλαμε να γνωρίζετε πως μπορείτε να ελέγξετε την αναπαραγωγή της ηχητικής περιγραφής χρησιμοποιώντας τα κουμπιά στην οθόνη της εφαρμογής στο κινητό τηλέφωνο. Αν γνωρίζετε πως να χρησιμοποιείτε smartphone, μπορείτε να δοκιμάσετε μόνοι σας. Διαφορετικά, μπορείτε να ζητήσετε βοήθεια από ένα εθελοντή ή τους ερευνητές σε περίπτωση που θέλετε να κάνετε παύση, να σταματήσετε ή να επανεκκινήσετε την ηχητική περιγραφή.

6. Μετά την περιήγησή σας, θα ερωτηθείτε για την εμπειρία σας με το ανάγλυφο και την ηχητική περιγραφή.

Interview sheet in Greek / Φύλλο συνέντευξης – Ανάγλυφο ρίσσας

Ερευνητής: Ημερομηνία: Τοποθεσία: Συμμετέχων/ουσα:

Ερωτήσεις

1. Ποια είναι η άποψή σας για την εμπειρία που είχατε ανακαλύπτοντας το ανάγλυφο με τη βοήθεια της ηχητικής εφαρμογής; (γενική εισαγωγική ερώτηση)

2. Θεωρείτε πως το ανάγλυφο και η ηχητική περιγραφή σας βοήθησαν να ανακαλύψετε περισσότερες πληροφορίες για το έκθεμα της ρίσσας; Πώς; (ερώτηση αντίληψης/επίγνωσης)

3. Υπάρχει κάτι που απολαύσατε ιδιαίτερα σήμερα κατά την ανακάλυψη του ανάγλυφου με τη βοήθεια της εφαρμογής; (ερώτηση ενδιαφέροντος/σύνδεσης*)*

4. Ποια νομίζετε πως είναι η σημασία/αξία της ύπαρξης τρισδιάστατα εκτυπωμένων αντικειμένων, τα οποία θα είναι διαθέσιμα στους μη βλέποντες και με μειωμένη όραση επισκέπτες του μουσείου; (ερώτηση συμπεριφορών/αξιών)

5. Αν σας παρείχαν παρόμοια τρισδιάστατα εκτυπωμένα εκθέματα και ηχητικές εφαρμογές, θα άλλαζε η αντίληψή σας σχετικά με τα ζητήματα προσβασιμότητας στα μουσεία; (ερώτηση συμπεριφορών)

6. Θα μιλούσατε σε άλλους για την εμπειρία που είχατε σήμερα με το τρισδιάστατα εκτυπωμένο ανάγλυφο της προθήκης; (ερώτηση συμπεριφορών/δεξιοτήτων)

7. Θα θέλατε να σχολιάσετε κάτι άλλο ή να μοιραστείτε κάποιες άλλες σκέψεις μαζί μας; (καταληκτική ερώτηση)

Observation sheet in Greek / Φύλλο παρατήρησης – Ανάγλυφο ρίσσας

Παρατηρητής: Ημερομηνία: Τοποθεσία: Ώρα εισόδου/εξόδου:

Προσωπικό πλαίσιο

Συμμετέχων/ουσα: Φύλο (κυκλώστε ένα): Γυναίκα Άνδρας Άλλο Ηλικία (περίπου, κυκλώστε ένα): 18-24 25-39 40-49 50-59 60 plus

Κοινωνικό πλαίσιο

Σύνθεση επίσκεψης (κυκλώστε ένα): Ατομική Ομαδική Αν πρόκειται για ομάδα: Πόσοι άνθρωποι στην ομάδα; Υπάρχει κάποιος υπεύθυνος;/Ποιος; Κοινωνικό περιβάλλον (κυκλώστε ένα): Συνωστισμένο Μη συνωστισμένο				
Κοινωνικές αλληλεπιδράσεις:				
Μέσα στην ομάδα ή μεταξύ διαφορετικών ομάδων/ατόμων/υπαλλήλων;	Ποιος μιλά σε ποιόν	Πότε συμβαίνει αυτό	Για ποιο πράγμα μιλούν, τι χρειάζονται;	Πως (μιλούν, κοιτούν, κάνουν κινήσεις;)

Φυσικό πλαίσιο

Περιγραφή ατμόσφαιρας (Σκοτεινά; Μυρίζει; Στενός χώρος; Έχει θόρυβο; Μαλακό/σκληρό πάτωμα; Προθήκη ψηλά/χαμηλά;)
Βρίσκουν οι άνθρωποι το έκθεμα εύκολα (χωρίς βοήθεια); ΝΑΙ ΟΧΙ Σχόλια:
Ελκύονται οι επισκέπτες από τη ρέπλικα; ΝΑΙ ΟΧΙ
Δίνουν προσοχή/διαβάζουν την επιγραφή σε Braille? ΝΑΙ ΟΧΙ Προσδιορίστε (αν είναι δυνατό):

Επικεντρώνουν την προσοχή τους στην ηχητική περιγραφή και/ή την εικόνα στην εφαρμογή και/ή την αφίσα της ρίσσας; Εγκαταλείπουν; Περιγράψτε:
Είναι εύκολη η λειτουργία και ο έλεγχος της εφαρμογής; Υπάρχουν προβλήματα; (ευχρηστία) Περιγράψτε:

Άλλα σχόλια/προτάσεις (σημειώσεις):

Questionnaire sheet in Greek

Ερωτηματολόγιο – Ανάγλυφο ρίσσας

Γενικά σχόλια

Ποια είναι τα σχόλιά σας για το περιεχόμενο του ανάγλυφου (π.χ. για τη σκηνή, τη λέξη σε Braille, το ηχητικό κύμα την κορυφή);

Αν είστε μερικώς βλέπων/ουσα, έχετε κανένα σχόλιο για την οπτική εντύπωση του ανάγλυφου (πχ. Για το χρώμα, τη γυαλάδα, την αντίθεση, την ανακλαστικότητα, τη φωτεινότητα, τη διαφάνεια);

Στοιχεία ανάγλυφου και εφαρμογή κινητού

Πώς διαμορφώνονται οι εντυπώσεις σας από το ανάγλυφο; Σε βαθμίδα από το 1 ως το 5 πόσο ευχαριστημένοι είστε από τα ακόλουθα στοιχεία του ανάγλυφου;

Μέγεθος

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Πολύ δυσαρεστημένος/η	Δυσαρεστημένος/η	Τίποτα	Ικανοποιημένος/η	Πολύ ικανοποιημένος/η

Σχήμα

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Πολύ δυσαρεστημένος/η	Δυσαρεστημένος/η	Τίποτα	Ικανοποιημένος/η	Πολύ ικανοποιημένος/η

Βάρος

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Πολύ δυσαρεστημένος/η	Δυσαρεστημένος/η	Τίποτα	Ικανοποιημένος/η	Πολύ ικανοποιημένος/η

Υφή

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Πολύ δυσαρεστημένος/η	Δυσαρεστημένος/η	Τίποτα	Ικανοποιημένος/η	Πολύ ικανοποιημένος/η

Θερμοκρασία

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Πολύ δυσαρεστημένος/η	Δυσαρεστημένος/η	Τίποτα	Ικανοποιημένος/η	Πολύ ικανοποιημένος/η

Ανθεκτικότητα *(αν το υλικό είναι ανθεκτικό)*

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Πολύ δυσαρεστημένος/η	Δυσαρεστημένος/η	Τίποτα	Ικανοποιημένος/η	Πολύ ικανοποιημένος/η

Αν δεν είστε ικανοποιημένοι με κάποια από τα χαρακτηριστικά του ανάγλυφου, πείτε μας πως θα θέλατε εσείς να είναι το ανάγλυφο.

Σε βαθμίδα από το 1 ως το 5 πόσο εύκολη ή δύσκολη ήταν η χρήση της εφαρμογής κινητού τηλεφώνου;

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Πολύ δύσκολη	Δύσκολη	Τίποτα	Εύκολη	Πολύ εύκολη

Σε βαθμίδα από το 1 ως το 5 πόσο ικανοποιημένοι είστε από την ηχητική περιγραφή του ανάγλυφου;

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Πολύ δυσαρεστημένος/η	Δυσαρεστημένος/η	Τίποτα	Ικανοποιημένος/η	Πολύ ικανοποιημένος/η

Προφίλ επισκέπτη

Διαβάζετε Braille; ☐ ΝΑΙ ☐ ΟΧΙ

Έχετε επισκεφτεί κάποιο μουσείο φυσικής ιστορίας;

☐ ΝΑΙ ☐ ΟΧΙ

Είναι η τωρινή/παρελθούσα απασχόλησή σας σχετική με την πολιτισμική κληρονομιά (απασχόληση σε μουσείο, βιβλιοθήκη, αρχείο, σχετική με τέχνες, ανθρωπιστικές σπουδές);

☐ ΝΑΙ ☐ ΟΧΙ Αν ναι, προσδιορίστε:

Πόσο συχνά είχατε την ευκαιρία να αγγίξετε μουσειακά αντικείμενα στο παρελθόν;

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Ποτέ	Σπάνια	Μερικές φορές	Συχνά	Πάντα

Έχετε χρησιμοποιήσει την τεχνολογία ως μέρος μίας μουσειακής επίσκεψης στο παρελθόν;

☐ ΝΑΙ ☐ ΟΧΙ

Τι περιμένατε να κάνετε ή να ανακαλύψετε κατά τη σημερινή δραστηριότητα;

Σας ενδιαφέρουν συγκεκριμένες συλλογές ή εκθέματα φυσικής ιστορίας;

Στοιχεία επισκέπτη

Φύλο

☐ Άνδρας ☐ Γυναίκα ☐ Άλλο

Ηλικία

☐ 18-24 ☐ 25-39 ☐ 40-49
☐ 50-59 ☐ άνω των 60

Εθνικότητα

☐ Λευκής καταγωγής ☐ Μεικτά εθνικά γκρουπ ☐ Ασιατικής καταγωγής
☐ Έγχρωμης καταγωγής ☐ Άλλο

Επίπεδο όρασης

☐ Μη βλέπων/ουσα ☐ Μερικώς βλέπων/ουσα ☐ Βλέπων/ουσα με κάλυψη ματιών

Αν είστε μη βλέπων/ουσα, έχετε μνήμη όρασης;

Σας ευχαριστούμε πολύ.

Audio description in Greek / Ηχητική περιγραφή – Ανάγλυφο ρίσσας

Προθήκη – γενική εισαγωγή (γενική άποψη/αναπαράσταση)

Πλησιάζετε μία προθήκη της Βικτωριανής εποχής που προέρχεται από το μουσείο φυσικής ιστορίας Booth του Brighton της Μεγάλης Βρετανίας. Η προθήκη περιέχει ένα βαλσαμωμένο πτηνό, τον τριδάχτυλο γλάρο ή ρίσσα, που στέκεται πάνω σε ένα βράχο και ατενίζει τον ορίζοντα.

Ανάγλυφο – γενική εισαγωγή (γενική άποψη/αναπαράσταση + θέση κάθε αντικειμένου)

Μπροστά σας στο τραπέζι υπάρχει μία απλοποιημένη απόδοση του περιεχομένου της προθήκης με τη μορφή ενός αναγλύφου. Ας ξεκινήσουμε με μία γενική περιγραφή της σκηνής που αναπαρίσταται και μετά θα προχωρήσουμε αναλυτικά στα επιμέρους στοιχεία. Παρακαλώ ακολουθείστε με τα δάχτυλά σας την περιγραφή καθώς η αφήγηση προχωρά.

Τώρα τοποθετήστε τα χέρια σας πάνω στο ανάγλυφο. Από το πάνω μέρος προς τα κάτω το ανάγλυφο παρουσιάζει:

- πρώτα μία σειρά από αλλεπάλληλους δίσκους που αναπαριστούν το ηχητικό κύμα του καλέσματος του τριδάχτυλου γλάρου
- ακριβώς από κάτω, υπάρχει η υπερυψωμένη ανάγλυφη φιγούρα ενός ενήλικου τριδάχτυλου γλάρου. Το πτηνό στέκεται σε προφίλ στάση πάνω σε ένα βράχο και κοιτάζει προς τα δεξιά
- στα αριστερά του πουλιού, ακριβώς πάνω από τα φτερά και το σώμα του, υπάρχει μία επιγραφή σε αγγλική Μπρέιλ με το όνομα του πτηνού
- ακριβώς κάτω από το σώμα του πτηνού θα συναντήσετε τα πόδια του που πατάνε πάνω σε βράχο
- στην επιφάνεια του βράχου υπάρχουν κάποιες υπερυψωμένες περιοχές που αναπαριστούν θαλάσσια φυτά, καθώς και μία μπάλα από αυγά θαλάσσιου σαλιγκαριού
- τέλος, στο κατώτερο μέρος του βράχου θα βρείτε την ανώμαλη επιφάνεια του βοτσαλωτού εδάφους που εκτείνεται σε όλο το πλάτος του αναγλύφου.

Ανάγλυφο - λεπτομέρειες (λεπτομερής περιγραφή: θέση, κατεύθυνση, υλικά, χρώματα)

Ας περιγράψουμε τώρα τα επιμέρους στοιχεία της σκηνής. Παρακαλώ ακολουθήστε με τα δάχτυλά σας καθώς η αφήγηση προχωρά.

Ξεκινήστε πάλι από το άνω μέρος του αναγλύφου. Στην κορυφή θα βρείτε την υπερυψωμένη αναπαράσταση του κύματος ήχου που παράγεται από το κάλεσμα της ρίσσας. Τα πιο ηχηρά τμήματα του καλέσματος αναπαρίστανται με τους μεγαλύτερους δίσκους ενώ τα πιο χαμηλόφωνα με μικρότερους.

Αυτό είναι το κάλεσμα του πουλιού *(ήχος καλέσματος πουλιού).*

Ας συνεχίσουμε τώρα με την εξερεύνηση του πτηνού που είναι η κεντρική και ψηλότερη φιγούρα του αναγλύφου. Στην κορυφή, βρίσκεται το κεφάλι του πτηνού. Εκεί μπορείτε να βρείτε και το στρογγυλό μάτι της ρίσσας. Αν κινηθείτε προς τα δεξιά θα ανακαλύψετε το μικρό μυτερό ράμφος του πουλιού. Οι τριδάχτυλοι γλάροι ή ρίσσες έχουν κίτρινα ράμφη που τους βοηθούν να πιάνουν γαρίδες, σκουλήκια και μικρά ψάρια για να τραφούν.

Αν μετακινήσετε τα χέρια σας χαμηλότερα και πιο κοντά στο σώμα του πουλιού θα νιώσετε τα ανάγλυφα φτερά του. Αυτά βρίσκονται σε υψηλότερο επίπεδο από το κυρίως σώμα του. Το σώμα και το κεφάλι του πτηνού είναι λευκά, ενώ οι φτερούγες του είναι γκρίζες με μαύρες απολήξεις.

Ακριβώς κάτω από το σώμα του πτηνού θα ανακαλύψετε τα κοντά πόδια του και τα πέλματά του που ακουμπούν πάνω στην επιφάνεια του βράχου. Τα πόδια της ρίσσας μπορεί να είναι μαύρα ή κόκκινα. Αυτό είναι ένα πτηνό με μαύρα πόδια. Το μήκος του ενήλικου γλάρου στην προθήκη, από την άκρη του ράμφους του ως την ουρά του, είναι περίπου 30-40 εκ. Ένα τέτοιο πουλί θα είχε άνοιγμα φτερών περίπου 90 εκ.

Ας περάσουμε τώρα στην εξερεύνηση του βράχου. Ακολουθήστε με τα δάχτυλά σας το υπερυψωμένο περίγραμμα του βράχου ακριβώς κάτω από τα πόδια του πτηνού. Στην προθήκη, ο βράχος είναι φτιαγμένος από πεπιεσμένο χαρτί και έχει βαφτεί γκρι για να μοιάζει με αληθινό βράχο.

Στην επιφάνεια του βράχου, κοντά στο κέντρο του και λίγο προς τα αριστερά, θα ανακαλύψετε ένα αντικείμενο με ακανόνιστο σχήμα που αναπαριστά μια μάζα από μπεζ φύκια που ξεβράστηκαν ή ξεράθηκαν πάνω στο βράχο. Στο αριστερό κάτω μέρος του βράχου υπάρχει άλλη μία ακανόνιστη μάζα από καφέ φύκια.

Τώρα ακολουθήστε και πάλι το περίγραμμα του βράχου με κατεύθυνση προς το δεξί κάτω άκρο του. Εκεί θα βρείτε μία σχεδόν οβάλ μάζα από αυγά θαλάσσιου σαλιγκαριού. Στην προθήκη η μάζα των αυγών έχει μπεζ χρώμα.

Αν τοποθετήσετε τα δάχτυλά σας στο κατώτερο άκρο του αναγλύφου, ακριβώς κάτω από το βράχο και τα φύκια, θα νιώσετε το ανώμαλο περίγραμμα του βοτσαλωτού εδάφους που εκτείνεται σε όλο το πλάτος του αναγλύφου. Το έδαφος στην προθήκη αποτελείται από μικρά βότσαλα και χαλίκι σε καφέ χρώμα.

Ρίσσα – γενική περιγραφή (σύνοψη)

Ας μιλήσουμε τώρα λίγο περισσότερο για τον τριδάχτυλο γλάρο ή ρίσσα. Το πτηνό ανήκει στην οικογένεια των γλάρων και σχηματίζει μεγάλες παράκτιες αποικίες σε όλη τη Μεγάλη Βρετανία. Το καλοκαίρι το είδος αναπαράγεται στο Βόρειο Ειρηνικό, το Βόρειο Ατλαντικό και τους Αρκτικούς Ωκεανούς. Το χειμώνα, οι ρίσσες περνούν τον περισσότερο καιρό τους στη θάλασσα και μπορούν να φτάσουν ως και τη Μεσόγειο. Το είδος δημιουργεί τις φωλιές του σε απόκρημνους βράχους και πιο σπάνια σε ανθρώπινες κατασκευές, όπως κτίρια. Το όνομα πτηνού στα αγγλικά είναι kittiwake και προέρχεται από το κάλεσμά του *(ήχος καλέσματος πουλιού).*

Sample of transcribed interview - Kittiwake relief study

Interviewer: Myrsini Date: 19.9.2017 Location: Blind Veterans Participant: PRT7-CS1

Questions and answers

INTERVIEWER

What do you think about the experience of exploring the relief with the help of the mobile device and the audio today? (General intro question)

PRT7-CS1

Excellent. I would like to see it really developed. And I would like to see how, you know, in what way could it be developed further to be very much more accessible for people like myself.

INTERVIEWER

Did the relief and audio help you to discover more information about the exhibit of the kittiwake? How? (Awareness/knowledge question)

PRT7-CS1

Absolutely yes, definitely. Well the description itself gave me an understanding of what was in front of me. And then to be able to do the description with the relief gave me an understanding of putting back into a shape, back into my mind. So basically, what I was able to do in the recesses of my mind, it was to imagine.. you know.. I mean I live by the seaside, so kittiwakes and seabirds I understand and it was just really lovely. You almost felt that you are actually looking at the real thing.

INTERVIEWER

Did you particularly enjoy anything about the experience with the relief today? (Engagement/interest question)

PRT7-CS1

I love the sound. And I love the idea of a tactile sound. It was just.. But that comes because of my.. basically because of my background in engineering.

INTERVIEWER

What do you think that is the value of having 3D printed objects available to the visually impaired and blind visitors of the museum? (Attitudes/values question)

PRT7-CS1

I think I would like to see it really much more available in museums and anywhere of that sort of nature. Purely from the point of view that I think we need our young people to be understanding the world around us. And I would really really like to be able to understand more, if I go to one (museum), to grasp -you know-more about what maybe I have lost in my memory. So, just I love history. It just of sort put it back in a more 3D, even if it is only in my

mind's imagination, you know.. And it probably won't look like anything what it does look like in my imagination to reality, but it doesn't matter. It just gives me that much more freedom of the feeling part of the real world.

INTERVIEWER

Would similar experiences with the provision of 3D printed objects and audio change your opinion about accessibility to museums? (Attitudes question)

PRT7-CS1

Hmmm. I think it would.. I'm not saying it would change my opinion because I think it is something I have always believed that we can do. I think that the joy would be that there would be even more access and more availability than what we have at the moment.

INTERVIEWER

Would it motivate you?

PRT7-CS1

Oh yeah, I mean I'll go anyway. I am already motivated, but I would like to think it would motivate young people more and that is where we desperately need to -you know- to work.

(Interruption by mobile phone call)----------

Well, as I said I'm already motivated, but what I would like to see is other people motivated. Now, I would also like to see people who have lost their sight as adults not to sit around at home, but to be able actually to do the things that they used to do when they had sight and still be able to enjoy them and be able to access and therefore find that love back again. That would be my dream.

INTERVIEWER

Would you talk to others about the experience that you had here today with the 3D printed relief of the display? (Behaviours & Skills question)

PRT7-CS1

Yes, happily. I mean when I do talks for Worthing, for sight support Worthing, I speak on behalf of guide dogs. I mean if I ever did, I would be very happy to, because we've had quite a lot of experience. Particularly with things like Maritime Museum, where we were doing some, they actually taught us some of the crafts and that was very tactile. They had to explain what sailors used to do and then they gave us the materials to have a go at and it was a one-off, you know, they do it in sort of Art-times. Yeah, I think these things, I mean I would, yeah, I would encourage anybody (laughs) for the fun of it.

INTERVIEWER

Is there anything else that you would like to comment on or share your thoughts about? (General ending question)

PRT7-CS1

No, I think the whole morning has been really interesting. I am fascinated by the 3D printer. I'd like to, you know, really sort of.. For me, I'd like to get my hands on it, but probably this would be a bit dangerous. Would it? No, but from this point of you this sort of relief I think it is one of their better reliefs. And it is simplistic, so we don't have to go into complications. I mean if you wanted more complicated, you can always do a complicated one for those who have sight problems, but are really more academic in that world. That's a different issue. No, I think it is brilliant.

Sample of transcribed observation sheet - Kittiwake relief study

Observer: Myrsini Date: 18.2.2019 Location: Cerb Time in/out: 7:30 min obs

Personal context

Participant: PRT14-CS1

Gender (circle one): Female Male Other

Age (approximately, circle one): 18-24 25-39 40-49 50-59 60 plus

Social context

Composition of visit (circle one): Individual Group

If a group: How many people are they? Is someone in charge? Who?

Social environment (circle one): Crowded Not crowded

Social interaction:

Inside the group or between different groups/individuals/officers?	Who talks to whom	When does this happen	What do they talk about or need?	How (talk, look, are physical?)
He asks me about the sound wave as soon as he finds it in order to seek for confirmation about his finding. Whenever he finds something, he asks me to corroborate his exploration and identification.				

Physical context

Describe atmosphere (Dark? Smelly? Narrow? Noisy? Soft/hard floor? Low/high display?)

The room where the interviews are taking place is the office of a staff member located on the second floor of the building CERB. There is plenty of natural light coming inside thought he two windows of the room. The room is small and is a bit messy, with several objects witnessing educational programmes where the visually impaired people participate. The are many posters on the wall. There is occasionally some noise from the people passing from outside, but we have the door closed in order to do the testing.

Do people find the exhibit easily (without help)? YES NO

Comments: Finds it easily but asks whether he can start "searching" on it.

Are they attracted by the replica? YES NO

Do they pay attention/read the Braille? YES NO Define (if possible): Immediately. He finds easily the label and reads it even before the description gets to this element. He says “kittiwake” smiling. Then asks me whether it says kittiwake.
Do they pay attention to the audio and/or image in the app and/or physical object? Do they quit? Describe: He is blind, hence pays attention to the audio and relief.
Is it easy to get the relief and associated application working and controlling it? Are there any problems? (usability) Describe: It is easy. He comments on the type of android phone and the beacon and its functionality as well.

Other comments/suggestions (notes):

He asks in the beginning is he can starts searching the relief. As soon as he starts the exploration, he finds the Braille and asks me “does it say kittiwake?”. He is keen to explore and recognise the elements. Moves quite quickly, faster that the description, and is extremely skilled. He locates everything quite easily. He is blind without visual memory and very skilled.

He had located almost everything before the detailed description. Goes faster than the description occasionally.

When he finds the ball of whelk eggs, he hits his fingers on top of it, as if he wanted to confirm his findings in this way.

Appendix C: Case study 2 - guidance, protocols, data samples

Interview sheet – Picasso pot study

Interviewer: Date: Location: Participant:

Questions

1. What do you think about the experience of exploring the 3D printed bird pot with the help of the video about Picasso's work today? *(General intro question)*

2. Did the 3D printed bird pot and video help you to discover more information about the exhibit of the "authentic replica" of Picasso's ceramics in the display? How? *(Awareness/knowledge question)*

3. Did you particularly enjoy of find inspirational anything about the experience with the 3D printed bird pot today? (*Engagement/interest question)*

4. What do you think is the value of having 3D printed objects available to the visitors of a museum? *(Attitudes/values question)*

5. Would similar experiences with the provision of 3D printed objects and complementing digital media, such as the video on the tablet, change the way you think about visiting museums? *(Attitudes question)*

6. Would you talk to others about the experience that you had here today with the 3D printed bird pot? *(Behaviours & Skills question)*

7. Is there anything else that you would like to comment on or share your thoughts about? (*General ending question)*

Observation sheet – Picasso pot study

Observer: Date: Location: Time in/out:

Personal context

Participant:

Gender (circle one): Female Male Other

Age (approximately, circle one): 18-24 25-39 40-49 50-59 60 plus

Social context

Composition of group visit:

How many people are they? Is someone in charge? Who?

Social environment (circle one): Crowded Not crowded

Social interaction:

Inside the group or between different groups/individuals/officers?	Who talks to whom	When does this happen	What do they talk about or need?	How (talk, look, are physical?)

Physical context

Describe atmosphere (Dark? Narrow? Noisy? Soft/hard floor? Low/high display?)

Do people find the exhibit easily (without help?) YES NO

Comments:

Are people attracted by the replica pot? (do they touch?) YES NO

Comments:

Do they pay attention to the replica or original pot or video or written info (do they quit)?

Describe:
Are there any issues with the video on the tablet? (related to usability) Describe:

Other comments/suggestions (notes):

Questionnaire sheet – Picasso pot study

General comments

What are your comments about the 3d printed bird pot replica (placed in front of the display to touch)?

Object features and video application

How well do you think that the 3d printed bird pot replica works for people like you? On a rating scale from 1 to 5 how satisfied are you with the following features of the 3d printed pot?

Colour

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

Brightness

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

Reflectance

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

Gloss

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

Size

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

Shape

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

Weight

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

Texture

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

Temperature

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

Durability *(whether the material is strong)*

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

If you are not satisfied with any of the features of the 3d printed bird pot replica, please tell us how you would like it to be.

On a rating scale from 1 to 5 how satisfied are you with the video complementing the 3d printed pot?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

Visitor Background

Have you visited other museums/galleries before?

☐ YES ☐ NO If yes, how many times per year? (please give a number): .....

Have you ever visited the Brighton Museum & Art Gallery before?

☐ YES ☐ NO

Is your current/past occupation/s related to the cultural heritage sector (museums, archives, libraries, arts etc)?

☐ YES ☐ NO If yes, please specify:

How often have you been provided with museum objects to touch before?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Never	Rarely	Sometimes	Often	Always

Have you used technology as part of a museum experience before?

☐ YES ☐ NO

What did you expect to do or explore during your visit today?

Are you interested in specific collections/objects of the Brighton museum?

Visitor Information

To which gender group do you belong?

☐ Male ☐ Female ☐ Other

What is your age group?

☐ 18-24 ☐ 25-39 ☐ 40-49 ☐ 50-59 ☐ 60 plus

What is your ethnic group?

☐ White ☐ Mixed/Multiple ethnic groups ☐ Asian/Asian British
☐ Black/African/Caribbean/Black British ☐ Other ethnic group

Approximately how many miles away do you live from the museum?

Thank you very much.

Sample of transcribed interview - Picasso pot study

Interviewer: Myrsini Date: 20.3.2019 Location: Brighton Museum Participant: PRT4-CS2

Questions - Answers

INTERVIEWER

What do you think about the experience of exploring the 3D printed bird pot with the help of the video about Picasso's work? *(General intro question)*

PRT4-CS2

I was delighted that I could touch what I could see on the video, and at first I was a little bit hesitant but there was this sign saying 'please touch' which is unusual. I read it twice (laughs), cause I'm so used to saying 'please do not touch', so that was really nice. And… yes it was nice to feel it and feel the weight and just look at how identical it is to the one that was on the display.

INTERVIEWER

Did the 3D printed bird pot and video help you to discover more information about the exhibit of the "authentic replica" of Picasso's work? *(Awareness/knowledge question)*

PRT4-CS2

I think it gave me much more of a view of his work... just looking at, you know, I mean I can see it's in style of Picasso but it's much nicer to be able to touch it and feel it. I don't know that I would ever use it myself (laughs).

INTERVIEWER

It has an unusual shape doesn't it? (laughs) Did you particularly enjoy or find inspirational anything about the experience with the 3D printed bird pot today? *(Engagement/interest question)*

PRT4-CS2

I think for me, touching it was, you know, a new experience, being able to touch an exhibit, whereas before you just look...yeah that was different for me.

INTERVIEWER

What do you think is the value of having 3D printed objects available to the visitors of a museum? *(Attitudes/values question)*

PRT4-CS2

I think for some people touching might be particularly if you, you know, your eyesight was impaired, being able to touch it and feel it. I think –you know- the different textures as

well...young people...children I think might be fun knowing that it's ok to do it, you know, that it wouldn't be the end of the world if they dropped it, such a thing. (laughs)

INTERVIEWER

Yes, yes. So, would similar experiences with the provision of 3D printed objects and complementing digital media, such as the video on the tablet, change the way you think about visiting museums? *(Attitudes question)*

PRT4-CS2

I think it would. I think it would be –you know- for example, if you had some of the Egyptian hieroglyphs so you could pick them up and touch them and all the vases, all bits and pieces...It would make it more real to be able to touch them, yeah.

INTERVIEWER

Would you mind knowing that these are replicas? So, they are machine- let's say-created, so we have captured the shape, the information with the scanners and then we have 3D printed them. So, would you mind if it weren't the original object but just an accurate, as much accurate as it can be, replica of it?

PRT4-CS2

I don't think I would. I think I'd be relieved that I touched it and it wasn't the original, you know.

INTERVIEWER

So, there is no danger of…

PRT4-CS2

No danger of damage or anything, yeah.

INTERVIEWER

Would you talk to others about the experience that you had here today with the 3D printed bird pot? *(Behaviours & Skills question)*

PRT4-CS2

Yes, yes. Of course, I will, yes.

INTERVIEWER

Is there anything else that you would like to add? (*General ending question)*

PRT4-CS2

Um..no no..I mean.. I don't know if this is a point, but at some point, selling these would perhaps bring an income for the museum? (laughs)

INTERVIEWER

(laughs). Yes, it is a thought and some museum are selling replicas that they have 3D printed. SO, I think that the Victoria and Albert has some and maybe the Natural History as well.

PRT4-CS2

Yes, yes. I'm not sure about whether I'd buy this one because I think that if I put flowers in it, it might look a bit odd...but maybe certain flowers (laughs)… some things, yeah.

INTERVIEWER

(laughs) It is a good idea. Thank you so much.

Sample of transcribed observation sheet – Picasso pot study

Observer: Myrsini Date: 4.4.2019 Location: Museum Time in/out: 5 min

Personal context

Participant: PRT15-CS2

Gender (circle one): Female Male Other

Age (approximately, circle one): 18-24 25-39 40-49 50-59 60 plus

Social context

Composition of group visit:

How many people are they? 4 Is someone in charge? Who? No

Social environment (circle one): Crowded Not crowded

Social interaction:

Inside the group or between different groups/individuals/officers?	Who talks to whom	When does this happen	What do they talk about or need?	How (talk, look, are physical?)
He turns to his friends to tell them about the replica/exhibit/video in excitement, but they are busy, so he turns back to the replica and exhibit.				

Physical context

Describe atmosphere (Dark? Narrow? Noisy? Soft/hard floor? Low/high display?)

We are in the main central gallery of the museum, at the end of the corridor and in front of the display with the bird pot. This spot has some light (not very bright neither dark) and the light from lamps is reflected on the glass of the display. The environment is calm and not noisy.

Do people find the exhibit easily (without help?) YES NO

Comments:

Are people attracted by the replica pot? (do they touch?) YES NO

Comments: Touches without lifting.

Do they pay attention to the replica or original pot or video or written info (do they quit)?

Describe: Replica, original pot, video.

Are there any issues with the video on the tablet? (related to usability)

Describe: Watches the video twice.

Other comments/suggestions (notes):

He watches the video once and looks at the original in the display. Then, he watches the video again and finally touches the replica without lifting it up. He spends quite a lot of time to observe the exhibit. He looks at the details thoroughly and observes the glazing. Looks at the original maybe to compare. Watches the video twice and is attracted by the replica, the label and the music.

Appendix D: Case study 3 - guidance, protocols, data samples

Interview sheet – Saltdean urn study

Interviewer: Date: Location: Participant:

Questions

1. What do you think about the activity with the 3D printed puzzle-pot that your family tried at the museum today? *(General intro question)*

2. Did the puzzle activity help you and your children to discover more about the original pot, the gallery or the way archaeologists work? How? *(Awareness/knowledge question)*

3. Did you particularly enjoy anything about the experience with the puzzle-pot today? (*Engagement/interest question)*

4. What do you think is the value of having 3D printed objects -such as the ones that are placed in front of the displays to touch- or similar activities available to the children when visiting a museum? *(Attitudes/values question)*

5. Would similar experiences with the provision of 3D printed objects and activities change the way you think about visiting a museum with the family? *(Attitudes question)*

6. Which skills have you and your children used in the puzzle activity today? Some example of skills could be: communication skills, problem solving, creative thinking, observational skills, making skills, practical skills and other). *(Skills question)*

7. Is there anything else that you would like to comment on or share your thoughts about? (*General ending question)*

Observation sheet – Saltdean urn study

Observer: Date:

Location: Time in/out:

Personal context

Participant:

Gender (circle one): Female Male Other

Age (approximately, circle one): 18-24 25-39 40-49 50-59 60 plus

Child/children:

Gender (circle and write numbers): Female Male Other

Age:

Social context

Composition of group visit:

How many people are they? Is someone in charge? Who?

Social environment (circle one): Crowded Not crowded

Social interaction:

Inside the group or between different groups/individuals/officers?	Who talks to whom	When does this happen	What do they talk about or need?	How (talk, look, are physical?)

Physical context

Describe atmosphere (Dark? Narrow? Noisy? Soft/hard floor? Low/high display?)

Are people attracted by the replica pot? (do they touch?) YES NO

Comments:

Do people assemble the puzzle-pot easily? Are there any problems? YES NO Comments:
Do they pay attention to the photo behind? YES NO Comments:
Do they pay attention to the original pot or labels or other relevant interpretative material? Describe:

Other comments/suggestions (notes):

Questionnaire sheet – Saltdean urn study

General comments

Do you have any comments about the puzzle activity and the replica of the puzzle pot?

Object features and activity

How well do you think that this pot replica works for people like you? On a rating scale from 1 to 5 how satisfied are you with the following features of the pot?

Colour

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

Brightness

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

Reflectance

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

Gloss

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

Size

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

Shape

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

Weight (of an individual piece)

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

Texture

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

Temperature

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

Durability *(whether the material is strong)*

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

If you are not satisfied with any of the puzzle's features, please tell us how you would like it to be.

On a rating scale from 1 to 5 how easy or difficult was for your family to assemble the puzzle?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very difficult	Difficult	Neither	Easy	Very easy

On a rating scale from 1 to 5 how satisfied are you with the puzzle activity?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Very unsatisfied	Unsatisfied	Neither	Satisfied	Very satisfied

Visitor Background

Have you visited other archaeological museums/galleries before?

☐ YES ☐ NO

Have you ever visited the Brighton Museum & Art Gallery before?

☐ YES ☐ NO

Is your current/past occupation/s related to the cultural heritage sector (museums, archives, libraries, arts etc)?

☐ YES ☐ NO If yes, please specify:

How often have you been provided with museum objects to touch before?

☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Never	Rarely	Sometimes	Often	Always

Have you used hands-on activities with your family in a museum before?

☐ YES ☐ NO

What did you expect to do or explore with your family during your visit today?

Are you interested in specific collections/objects of the Brighton museum?

Visitor Information

To which gender group do you belong?

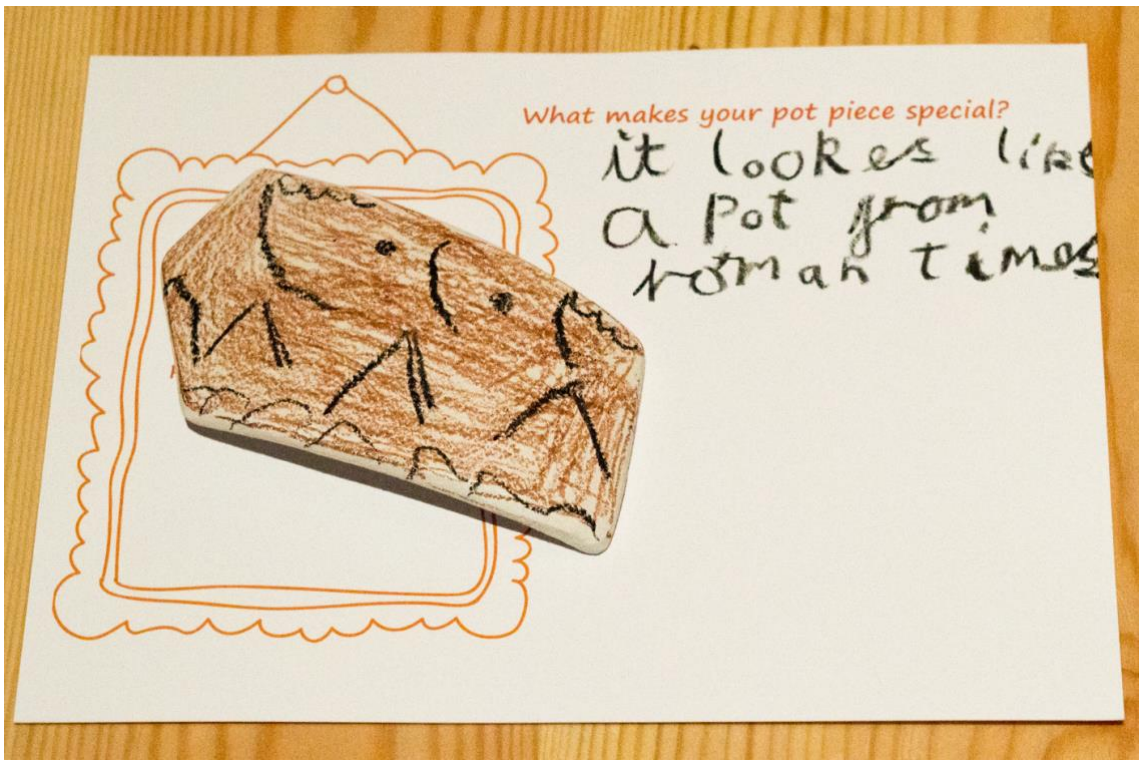
☐ Male ☐ Female ☐ Other

What is your age group?

☐ 18-24 ☐ 25-39 ☐ 40-49 ☐ 50-59 ☐ 60 plus

Thank you very much.

Artefact card for children – Saltdean urn study



Sample of transcribed interview – Saltdean urn study

Interviewer: Myrsini Date: 29.05.2019 Location: Brighton Museum Participant: PRT3-CS3

Questions – Answers

INTERVIEWER

What do you think about the activity with the 3d printed puzzle-pot that your family, actually you and your son tried at the museum today? (General intro question)

PRT3-CS3

I think for me, I'm a primary school teacher, so I'm always looking at different ways of trying to engage..

INTERVIEWER

Children..

PRT3-CS3

No, not just children but – you know – to foster interest in these sorts of things. So, you know, I really enjoyed it. I thing that anything that can physically engage people with not just looking at things is wonderful.

INTERVIEWER

Did the puzzle activity help you and your children to discover more about the original pot, the gallery or the way archaeologists work? (Awareness/knowledge question)

PRT3-CS3

I think if I had known that the original was on display as well then perhaps more so..

INTERVIEWER

To connect it to the original artefact, somehow. The relation is missing something.

PRT3-CS3

Yeah.

INTERVIEWER

Did you particularly enjoy anything about the experience with the puzzle-pot today? (Engagement/interest question)

PRT3-CS3

Um..I really liked the idea that it gives you in a really..I know it's a very basic sense but in how these things can be pieced together – you know – on the process.

INTERVIEWER

What do you think is the value of having 3d printed objects -such as the ones that are placed in front of the displays to touch- or similar activities available to the children when visiting a museum? Is there any value? (Attitudes/values question)

PRT3-CS3

I think definitely. Different types of learning, different ways of engaging. And I think just walking around can be..it just makes you feel tired, just looking. So I think actually moving and being involved physically, it brings a whole different dimension.

INTERVIEWER

And this related to my next question which is about whether similar experiences with the provision of 3d printed objects and activities change the way you think about visiting a museum. (Attitudes question)

PRT3-CS3

Oh, definitely. Just of even… from a work point of view as well, whenever we take the children out to a workshop or some kind of engagement. Definitely brings that learning to a different level.

INTERVIEWER

And I know that you assembled the puzzle at different times but are there any skills involved it that? Maybe you or children have used some skills when assembling this puzzle activity, some of this could be communication - obviously you did it separately so it's not the case - problem solving, creative thinking, observational skills, making skills, practical skills and other). (Skills question)

PRT3-CS3

All of those things. And even – you know – that I don't find shapes and gaps and mathematical..

INTERVIEWER

Is there anything else that you would like to comment on or share your thoughts about? (General ending question)

PRT3-CS3

I don't think so. I just think it's generally a very good idea to do this sort of things.

Sample of transcribed observation sheet – Saltdean urn study

Observer: Myrsini Date: 9.6.2019

Location: Museum Time in/out: 3 min

Personal context

Participant: PRT16-CS3

Gender (circle one): Female Male Other

Age (approximately, circle one): 18-24 25-39 40-49 50-59 60 plus

Child/children: 2

Gender (circle and write numbers): Female Male Other

Age: 8 (they are twins)

Social context

Composition of group visit:

How many people are they? 5 Is someone in charge? Who? Parents and grandmother

Social environment (circle one): Crowded Not crowded

Social interaction:

Inside the group or between different groups/individuals/officers?	Who talks to whom	When does this happen	What do they talk about or need?	How (talk, look, are physical?)
They talk to each other constantly. The grandmother helps the children by corroborating their movements and findings. She provides some directions in the beginning. "That's it!" when they place a piece correctly. Grandmother intervenes when one of the girls tries to grab a piece from the other girl and brings them back to order.				

Physical context

Describe atmosphere (Dark? Narrow? Noisy? Soft/hard floor? Low/high display?)

We are in the New Archaeology Gallery. The Gallery due to its lighting is a bit dark always. Space in the exhibit/puzzle-pot area is very narrow. The space in the middle is more wide and this is where interviews take place along with children's activity. Floor is hard in the exhibit area and soft in the interviews area. The pot is

placed at a medium height in the corner of the Iron Age corner/section of the exhibition. The gallery currently is not crowded. The environment is very calm.
Are people attracted by the replica pot? (do they touch?) YES NO Comments: Yes. Grandmother sees it alone and takes children there, as soon as they finish watching videos.
Do people assemble the puzzle-pot easily? Are there any problems? YES NO Comments: Yes. Children alone and grandmother praising children. She provides directions verbally in the beginning. Brings things to order when one child tries to grab the other child's piece.
Do they pay attention to the photo behind? YES NO Comments:
Do they pay attention to the original pot or labels or other relevant interpretative material? Describe: Puzzle and photo and original. They relate to original.

Other comments/suggestions (notes):

Grandmother sees the activity while children are watching videos (in the screen about science in the exhibition). She mentions it to mother and when children finish with videos, she takes them to the puzzle activity. She provides some directions in the beginning. "That's it!" when they place a piece correctly. Grandmother intervenes when one of the girls tries to grab a piece from the other girl and brings them back to order.