

ENRICH

Enhancing the Digital Inclusivity of Cultural and Natural Heritage

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INTERDISCIPLINARY RESEARCH

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Introduction

Emilo Rossi, Ramón Rubio Garcia, Rebecca Rouse

This report contains a synthesis of studies performed by staff involved in the **ENRICH Project** – ‘*Enhancing the Digital Inclusivity of Cultural and Natural Heritage*’ – at the ‘Gabriele d’Annunzio’ University of Chieti-Pescara (UdA, Italy), at the University of Oviedo (UNIOVI, Spain), and at the University of Skövde (HiS, Sweden). ENRICH is a 14-month collaborative research activity funded by **INGENIUM European University**¹ (co-funded by Erasmus+). Data presented in this report are part of the project activity No.1 ‘Knowledge Production’.

The ENRICH Project

Cultural and natural heritage hold global significance and require interdisciplinary efforts to make sites inclusive for all visitors, including those with physical or cognitive disabilities. Regardless of dimension, geographical location, socio-economic status, or cultural value, ensuring that heritage sites are fully accessible and enjoyable for all users is a crucial mission for any country aspiring to meet international key policies on ‘inclusive heritage’ (see: UNESCO’s WHC, ICOMOS, European Commission, NEB). The goal of making cultural and natural heritage sites fully enjoyable for all users is paramount to demonstrating a commitment to the democratic use and consumption of resources (see: European Green Deal, SDGs).

Today, the concept of ‘inclusive heritage’ mainly focuses on the physical aspects of the visitor experience, meaning that the physical accessibility of sites is the main parameter considered to make heritage democratic. Other conditions, such as blindness, cultural diversity, and the power of digitalization for enhanced visitor experiences, receive little attention. Moreover, the use of digital means is seldom considered, apart from online promotion and dissemination, despite evidence that digital innovations can significantly contribute to making sites more inclusive.

Sites that are inclusive from a digital perspective are more accessible and usable for all users, including those with various psychophysical or cognitive (dis)abilities, as well as other target groups such as the elderly and children. Remote digital visits can maximize financial investments, and the concept of ubiquitous heritage could be promoted. Additionally, digital storytelling techniques can expand the pedagogical value of immersive visit experiences, while new improvements can be achieved by employing 3D printing and AR/VR solutions.

¹ See: <https://ingenium-university.eu/>

The ENRICH project is based on the philosophy of ‘good design enables, bad design disables’ (EIDD, 2004) applied to cultural and natural heritage (EIDD, 2005) and aims to propose and experiment a novel interdisciplinary knowledge framework that makes cultural and natural heritage digitally inclusive. This will be achieved by combining inclusive design, digital storytelling, and digital modeling, which are the innovative subjects used to create engaging and inclusive visitor experiences for all potential users, including those with physical or cognitive disabilities. The use of modern technologies to promote digital inclusivity is at the core of this multidisciplinary study led by scholars from different backgrounds, and it is the first of its kind for the scopes and disciplines involved. Tests will be performed to assess the validity of the developed models.

Structure of the Report

This report is organized into three distinct yet interrelated sections that collectively explore the digital inclusivity of cultural and natural heritage.

The first section, *‘Design Studies on the Digital Inclusivity of Cultural and Natural Heritage’*, examines relevant literature and case studies, as well as the methodologies and research frameworks employed to enhance accessibility and engagement with cultural artifacts and natural areas in a digital context. This part is authored by scholars at UdA.

The second section, *‘Studies on the Manufacturing Technologies Used for the Digital Inclusivity of Cultural and Natural Heritage’*, delves into the various technological advancements and practices that facilitate the digital representation and preservation of heritage sites and objects, with a focus on 3D printing and advanced technologies. This part is authored by scholars at UNIOVI.

The third section, *‘Dramaturgical Impacts of Digital Technologies and Inclusive Design Methods for Natural and Cultural Heritage Storytelling’*, investigates how narrative techniques and immersive technologies can enrich visitor experiences, making heritage more engaging and informative. This part is authored by scholars at HiS.

Together, these sections aim to provide a comprehensive understanding of the intersection between design studies, digital technology, and cultural preservation, particularly highlighting the crucial role of investigating digital inclusivity to ensure that diverse cultural narratives are represented and accessible in the digital realm. By examining how design practices can bridge gaps in technology, this work emphasizes the importance of creating platforms that not only preserve cultural heritage but also engage underrepresented communities, fostering a more inclusive dialogue around the significance of culture in a digital age.

Materials and relevant documents are available on the ENRICH Project's website (2024) and are released under Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International license (CC BY-NC-SA 4.0)².

References

ENRICH Project. (2024). *Homepage*. Available at: <https://sites.google.com/view/enrichproject>

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European Institute for Design and Disability. (2005). *Culture for All: The Berlin Act 2005*. Adopted on 13 May 2005 at the EIDD Annual Conference of the European Institute for Design and Disability in Berlin.

² See: <https://creativecommons.org/licenses/by-nc-sa/4.0/deed.en>

Design Studies on the Digital Inclusivity of Cultural and Natural Heritage³

Emilo Rossi, Sarah Jane Cipressi, Francesca Caramanico, Erika Ferrara, Cristina Iacobucci, Cecilia Molon, Ester Tagliafierro

This essay explores the evolving concept of 'Inclusive Heritage' within Design, emphasizing the importance of valuing both cultural and natural heritage as shared resources that must be preserved for future generations. With a focus on recent literature and case studies, it outlines practical strategies for enhancing accessibility, visitability, and adaptability in heritage sites, while advocating for the involvement of historically marginalized communities in the design process. By integrating principles of inclusive design, this part of the report presents guidelines aimed at creating equitable access to heritage experiences, ultimately fostering a deeper understanding and appreciation of our collective cultural legacy across multiple identities and abilities.

Design for an Inclusive Heritage

Valuing Cultural and Natural Heritage has recently gained new significance and increased scientific attention within the Design community worldwide (Barcarolo, 2017). As stated by Falser (2015), we may encompass several tangible and immaterial assets with a high collective worth by utilizing the term 'heritage'. Indeed, both cultural resources – those artifacts that primarily embody the magnificent expression of human legacy and its *genius loci* – and environmental places – those remarkable natural landscapes that are the product of the ongoing molding action of natural phenomena – can be included under this umbrella term.

³ Study conceptualization and design (Emilio Rossi); methodology (Emilio Rossi and Sarah Jane Cipressi); data analysis (Emilio Rossi, Sarah Jane Cipressi, Francesca Caramanico, Erika Ferrara, Cristina Iacobucci, Cecilia Molon and Ester Tagliafierro); data review and validation (Emilio Rossi Sarah Jane and Cipressi). All authors have contributed to the production of this work; however, the writing of the various sections is attributed as follows: 'Abstract' to Emilio Rossi; 'Design for an Inclusive Heritage' to Sarah Jane Cipressi; 'Research methodology' to Francesca Caramanico; 'Classification of Studies: Clusters and Sub-Clusters' to Erika Ferrara; 'Nature of Studies and Methods Surveyed' to Cristina Iacobucci; 'Selected Case Studies' to Cecilia Molon, 'Design Guidelines' to Ester Tagliafierro; 'Conclusions' to both Rossi and Cipressi. All authors have read and agreed to the published version of the work.

The UNESCO Convention Concerning the Protection of the World Cultural and Natural Heritage (UNESCO, 1972) defined the world's heritage as all of its natural and cultural assets, both material and immaterial, whose immense value is widely acknowledged as belonging to everyone and, thus, to the current and future populations of the world. Two distinct meanings are alluded to by the desire to involve future generations in the enjoyment of current heritage:

1. The desire to conserve and enhance historic memory, environmental conditions, and social impacts of sites.
2. Echoing the concept of Sustainable Development, the protection policies, and the future enjoyment of the assets in their current state.

The idea of 'Inclusive Heritage' demands that designers everywhere adopt a fresh viewpoint (Barcarolo & Rossi, 2018). In terms of social challenges, new product creation, and economic effect, it has gained strategic significance. It also highlights how crucial it is to develop physical and digital solutions that respect and represent the many histories from the standpoint of enriching the cultural values represented by either natural or manufactured locations. Inclusive Heritage Design must be a collaborative process including several stakeholders, especially historically marginalized groups, as nations grow more multicultural. In the end, this strategy guarantees that cultural manifestations are maintained and honored by acknowledging the subtleties of many identities and creating an atmosphere where everyone feels appreciated and represented (Souto et al., 2023).

The proliferation of studies and practical experimentations made in the last decades and aimed to investigate how to create inclusive conditions and solutions to make the heritage inclusive for all, confirms of the attention of the design community on the creation of societal effects that are primarily intended to last over time. Acting locally to produce global stances is seen as paramount to place the interventions within virtuous sustainable actions.

To create suitable environmental and instrumental conditions for the inclusive fruition, studies developed by some notable institutions (Federparchi & FISH, 2003; UNWTO & Fundación ACS, 2015; UNWTO, 2016) suggest the adoption of three key-strategies:

1. Enhancing the accessibility of sites: the possibility to access to sites and/or service spaces using fixed or flexible solutions placed in the gates and in the thresholds.
2. Improving the visitability of sites: the opportunity to autonomously visit the sites using fixed or flexible solutions arranged along the crowded routes and/or in services spaces.
3. Boosting the adaptability as a quality for all sites: the possibility to act in the environments to improve the level of visibility and/or accessibility.

Incorporating inclusive design principles that accommodate a range of abilities, encouraging accessibility in public heritage sites, and using technology to create immersive and interactive experiences that tell a variety of stories are additional crucial steps in achieving Inclusive Heritage Design. For example, heritage places can be made inviting and navigable for everyone by creating surroundings and goods that are useable and accessible by everyone, regardless of age, ability, or status (Rossi & Barcarolo, 2018). Furthermore, accessibility includes both sensory

and cognitive aspects in addition to physical characteristics, guaranteeing that all visitors may interact with and enjoy cultural heritage (Ferrucci, 2022).

Technology integration offers chances to improve and democratize cultural heritage experiences. Applications for virtual reality (VR) and augmented reality (AR) can offer immersive experiences that break down the conventional boundaries of physical space and enable users to interact creatively with historical artifacts and narratives (Podara et al., 2021). Digital storytelling projects that enable community members to share their own stories, for instance, can empower people by providing them with a forum to express who they are and enhance our understanding of legacy (Podara et al., 2021).

On the social side of the design practice, community involvement in the design process is paramount. Involving local people, particularly those from underrepresented groups, creates a cooperative environment that may result in more accurate depictions of identity and history (Barcarolo, 2017; Barcarolo & Rossi, 2018). Heritage design can question prevailing narratives and advance a more comprehensive understanding of cultural legacies by appreciating the contributions of multiple stakeholders, such as indigenous peoples, ethnic minorities, and other underrepresented groups.

Embracing inclusivity into heritage architecture enhances society's collective memory and identity while also acknowledging the histories of all community members, fostering a more cohesive and linked environment for both current and future generations. In an increasingly varied society, inclusive heritage design can act as a crucial link between the past and the present, promoting comprehension, admiration, and a feeling of community. In order to ensure that all opinions are heard and that heritage places represent the diverse range of human experience, it is imperative that planners, designers, and community leaders give inclusion top priority as we proceed.

Research Methodology

This section of the research is mainly focused on the analysis of studies concerning the digital inclusivity of Cultural and Natural Heritage. To provide completeness in the sample of works collected as well as improved phenomenological analysis and discussion of results, a threefold research process consisting in distinctive research stages was used. The stages are described below:

Stage 1: Literature Review

Literature review was used to provide comprehensive overview of existing research and scholarly work linking inclusive design (in its broader meaning) and the digital application to either cultural or natural heritage. Key findings, methodologies, and theoretical frameworks were identified between potentialities and critical issues for later use in this international research.

To examine the connections between these disciplinary fields, a thorough systematic review of the literature was carried out using PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) as a main methodology (Petticrew & Roberts, 2006; Moher et al., 2009). Therefore, three methods were used to conduct this research stage: (i) searching for relevant sources within bibliographic databases (Scopus), (ii) refinement of the sample of works to consider for the study, and (iii) data analysis and development of a bibliometric networks.

Operatively, relevant terms were used to identify a suitable searching strategy and matchings within titles, keywords, and abstracts. Four specific search queries were used to identify a complete set of records. In terms of timespan, the analysis was restricted to only studies written in English and conducted in the last twenty-five years (1999–2024). Only articles, reviews, and chapters were selected due to the rigorous peer-review process prior to publication. The synthesis of the Scopus search is shown in Table 1.

Table 1: Scopus queries used in the literature review.

N.	Simplified Query	Records found	Deleted items
1	Heritage + inclusi* + digit* + design*	183	0
2	Heritage + inclusi* + design*	389	41 deleted due to double records
3	Heritage + inclusi* + digit* + design*	49	49 deleted due to double records
4	Heritage + inclusi* + digit* + enhanc*	28	27 deleted due to double records

Overall, this research approach enabled a comprehensive collection of 532 records, which later served as the foundation for conducting the bibliographic analyses.

From this analysis, the use of PRISMA protocol – Identification, Screening, Eligibility, Inclusion – (Moher et al., 2009) enabled to identify a sample of 90 works from which to operate the literature review. These works were used to extract research patterns as well as cluster and sub-clusters describing the research trends in the field. Results are discussed in the sections entitled ‘*Classification of Studies: Clusters and Sub-Clusters*’ and ‘*Nature of Studies and Methods Surveyed*’.

Stage 2: Case Study Analysis

The analysis of case studies was conducted with the aim of identifying examples of best practices that can contribute to the development of design guidelines for digital inclusivity in the field of Cultural and Natural Heritage. Through structured mapping and the selection of already implemented projects, the aim was to highlight how inclusive technologies and approaches have been used to enhance accessibility, experience, and conservation of heritage.

The research and selection process was divided into four strategic phases that played a crucial role in gathering useful data. Specifically:

1. Design of the database and definition of classification categories.
2. Collection of case studies.
3. Analysis of case studies.
4. Generalization of data and definition of design guidelines.

An extensive discussion of this stage as well as its results are discussed in the section entitled '*Selected Case Studies*'.

Stage 3: Design Guidelines

The analysis of case studies was used to identify a set of design guidelines depicting the main design trends used by the design community in developing inclusive digital solutions for the enhancement of Cultural and Natural Heritage. An extensive discussion of this stage as well as its results are discussed in the section entitled '*Design Guidelines*'.

Classification of Studies: Clusters and Sub-Clusters⁴

The classification of studies within the domain of inclusive digital heritage was based on the sample of studies identified through Scopus search and was later effectively organized into distinct clusters and sub-clusters. The PRISMA protocol (Moher et al., 2009). VOSviewer was used to interpolate the authors' keywords to generate a co-occurrence network. This process allowed to emphasize transparent and systematic reporting in research discussed in the following four sub-sections.

Overall, this classification of studies not only aids researchers in identifying gaps in current literature but also encourages interdisciplinary collaboration, informs policy-making, and promotes inclusive practices that are essential in the stewardship of our shared digital heritage. By understanding the intricate relationships among these clusters and sub-clusters, stakeholders can better navigate the complexities of heritage preservation in an increasingly digital world.

Cluster 1: Social and Societal Aspects about the Inclusive Digital Heritage

The first cluster, 'Social and Societal Aspects about the Inclusive Digital Heritage', serves as a foundational category that emphasizes the crucial role of social dynamics in shaping our understanding and accessibility of heritage. Sub-cluster 1A, focused on inclusion-related issues, illustrates a growing recognition of the need for diverse voices in the documentation and preservation of cultural and natural heritage. With 27 studies contributing to this body, researchers explore themes such

⁴ The complete set of case studies is available in Annex 1.

as community engagement, representation of marginalized groups, and the implications of digital divide phenomena on heritage accessibility. Sub-cluster 1B enriches this discourse by examining broader societal issues, with its 10 studies often addressing challenges such as political influence, economic disparities, and shifting cultural narratives that can affect heritage legitimacy and recognition.

Cluster 2: Physical and Digital Dimensions of the Heritage

The second cluster, 'Physical and Digital Dimensions of the Heritage' provides a complementary lens through which to examine the materiality of heritage alongside its digital manifestations. In sub-cluster 2A, 43 studies delve into the tangible aspects of heritage, discussing preservation techniques, conservation challenges, and the social significance of physical artifacts. The intersection between the physical and digital worlds becomes apparent when examining sub-cluster 2B. Here, the 18 studies highlight how digital technologies can augment our interaction with physical heritage, including virtual tours, digital archiving, and other innovative platforms that facilitate broader public engagement and democratization of access to heritage resources

Cluster 3: Modelling and Representation of the Digital Heritage

The third cluster, 'Modelling and Representation of the Digital Heritage' shifts focus toward the methodologies of data handling and presentation. Sub-cluster 3A emphasizes the significant technological advancements in data modeling, encompassing 19 studies that investigate how emerging technologies – such as AI, machine learning, and big data analytics – enhance the gathering and processing of heritage data. On the other hand, sub-cluster 3B highlights the importance of digital representation, with 26 studies exploring various modalities for displaying and interacting with data. Researchers in this sub-cluster investigate the effectiveness of different visualization techniques, the role of user experience in digital interfaces, and the potential for interactive storytelling approaches to engage audiences meaningfully.

Cluster 4: Design for the Inclusive Digital Heritage

The forth cluster, 'Design for the Inclusive Digital Heritage' embodies a multidisciplinary approach that spans design, communication, and technology. In sub-cluster 4A, the 8 studies emphasize the importance of integrating inclusive design principles across various disciplines – such as graphic design, UX/UI design, and architecture – ensuring that digital heritage resources are accessible to all users, including those with disabilities. Sub-cluster 4B further articulates the necessity of effective communication strategies within heritage projects, where 6 studies underscore the impact of narrative framing, educational outreach, and participatory practices that foster community involvement and ownership in heritage conservation.

Nature of Studies and Methods Surveyed

In terms of the nature of studies identified in the literature review, both experimental and speculative studies were identified. An overview of this classification is shown in the following sub-sections.

Experimental and Speculative Studies

The study of digital inclusivity for Cultural and Natural Heritage embraces both experimental and speculative approaches, each contributing unique perspectives. Experimental studies (Table 2) rigorously evaluate existing technologies and methodologies to enhance accessibility and representation in heritage preservation. Speculative studies (Table 3) encourage innovative thinking, envisioning future possibilities and addressing ethical implications. Together, these approaches deepen the understanding of how digital tools can promote inclusivity and ensure diverse voices are represented in the narrative of our collective heritage.

Table 2: Sample of experimental studies recorded.

Experimental Studies (sample)	
Aim	Contribution
Creating and sharing 3D digital replicas of archaeological sites online (Wessels et al., 2023).	A paradigm of archaeological visualisation to propose recommendations for inclusive decolonised visualisations of living heritage and archaeological places.
Proactive preservation of Pesaro's urban art (Italy) – inclusively regeneration through dialogues with stakeholders (Baratin et al., 2022).	A set of interdisciplinary activities including a) citizen engagement, b) a digital catalogue and an interactive map available to all citizens comprising product information, executive techniques, conservation information, and interviews with artists.
Developing of an inclusive research model for urban heritage (Trovato, 2023).	Use of social networks as connection platforms with participatory channels to promote the urban regeneration.
Identify how to design digital heritage applications for social cohesion and how to measure it (Pescarin et al., 2023).	Design of a cultural probe kit used to identify the design elements on top of which a collaborative and hybrid prototype was developed.
Improving the knowledge, conservation, enhancement and accessibility of heritage sites and to make them a resource for national and local development (Giuffrida et al., 2021).	A multi-methodological approach including close-range photogrammetry, laser scanning and chemical, and thermal analyses.

Table 3: Sample of experimental studies recorded.

Speculative Studies (sample)	
Aim	Contribution
Re-establishing connections and cultivating a sense of belonging within rural communities, while safeguarding their cultural heritage (Del Soldato and Massari, 2024).	Understanding of the role of digital and creative strategies in rural communities, highlighting their significance in preserving food heritage, culture and community capital while driving economic development.
The role definition, difficulties and solutions, innovation services, and prospects of public libraries, with an emphasis on heritage (Sung and Tsai, 2022).	In-depth interviews with ten public library directors and division chiefs, along with expert consultation with three national library directors.
Looking at the digital technologies used in digital museums to improve the visiting experience (Hijazi and Baharin, 2022).	Inclusion of digital technologies (i.e., Wearable Devices, AI, Gesture Technology, Mobile Technologies, GPS tracking, etc.), to enhance the visitor's experience in museums.
Searching for new forms of sustainable and active fruition of cultural heritage, as well as dynamics for social participation (Maietti, 2023).	A conceptual framework or possible outline to foster the use of digital technologies through a set of integrated bottom-up and top-down actions.
Cover the lack of structured methodology in the design and development of inclusive virtual spaces in cultural heritage (Anastasovitis et al., 2024).	A multidisciplinary holistic framework comprising virtual museology, computer games, creative industries.

Design Methods

In terms of design methods, the sample of studies underlined the adoption of the methods discussed below.

1. Co-Design.

Co-Design involves the active participation of users and stakeholders in the design process, fostering collaboration and encouraging citizen-driven innovation. By integrating public engagement methodologies, this approach ensures that diverse perspectives shape outcomes, leading to more relevant and inclusive solutions.

2. Experimental Design.

Experimental Design in design research employs structured methodologies to test hypotheses and assess the effectiveness of specific interventions. Supported by literature reviews, this method allows researchers to systematically explore variables, refine design ideas, and validate concepts in real-world contexts.

3. Phenomenological Analysis.

Phenomenological analysis focuses on understanding users' lived experiences and perceptions. In design, this method seeks to uncover the essence of user interactions with products or services, providing deep insights that inform empathetic and contextual design decisions.

4. Literature Review and Critical Evaluations.

Literature reviews and critical evaluations synthesize existing research and design

practices to identify gaps and opportunities in the field. They provide a foundational understanding that informs future design strategies and helps evaluate the effectiveness of existing methods.

5. Qualitative Design and Iterative Design Research Models.

Qualitative Design emphasizes gathering in-depth insights through interviews, focus groups, and observations. Coupled with Iterative Design Research models, this approach allows for continuous refinement of design based on user feedback, fostering higher levels of engagement and relevance.

6. Ethnographic Research.

Ethnographic Research immerses designers in the cultural and contextual environments of users, enabling a comprehensive understanding of behaviors, needs, and values. This qualitative approach facilitates the design of products and services that resonate with specific communities and lifestyles.

7. New Research and Design Models.

New Research and Design Models advocate for innovative frameworks that challenge traditional design processes. These models often incorporate interdisciplinary perspectives and emerging technologies, aiming to address complex societal issues and enhance user engagement.

8. Inclusive Research Methods.

Inclusive Research Methods prioritize accessibility and participation from marginalized groups in the design process. By employing strategies that accommodate diverse needs, these methods aim to create equitable design outcomes that reflect a wide range of user experiences.

9. Strategic Research.

Strategic Research merges transition studies with social inclusion, focusing on long-term systemic change. This approach examines the interplay between design interventions and societal dynamics, ensuring that design initiatives are aligned with broader social goals and inclusivity.

10. Others.

Other methods in design research may include visual ethnography, action research, participatory design, and system thinking, all contributing to a richer understanding of user needs and promoting effective, sustainable design solutions.

Selected Case Studies

As briefly discussed in the Methodology section of this part of the report, The analysis of case studies was conducted with the aim of identifying of relevant examples and best practices to be later for the identification of notable interventions made by the design community and, later, to be used for the definition of a set of design guidelines for digital inclusivity in the field of Cultural and Natural Heritage. The research and selection process was divided into four phases described in the following sub-sections.

Design of the Database and Definition of Classification Categories

The creation of a database was made by using Airtable, which allowed to catalog the case studies in an organized and accessible manner. To facilitate the collection and the analysis of data collection, several key entries representing the main aspects of the study were defined. These included:

- Type of heritage: cultural, natural, or mixed.
- Short description: a summary of the case study to describe its objectives, context, and relevance to our study.
- Inclusivity dimension: classification of the inclusivity aspect addressed according to the lenses of Equality, Diversity, and Inclusion (EDI), which is to say:
 - Equality focuses on equality in access to and use of resources or services. The concept of access implies that everyone has the opportunity to access projects or solutions without barriers, while use refers to the availability of those resources equitably, ensuring that anyone can use them under equal conditions, without discrimination based on status, ability, or background;
 - Diversity refers to the variety of differences among people, which can include physical and cognitive aspects. In this context, design must consider users with different physical and cognitive abilities (e.g., people with reduced mobility, individuals with learning difficulties, etc.);
 - Inclusion goes beyond mere access; it concerns design that ensures the active participation of every individual, regardless of their differences. This implies that the project's goals and strategies are structured to ensure that all users can not only access the system but also benefit from it effectively.
- Specifications on the dimension of inclusivity.
- Digital inclusivity: a description of the type of digital solution adopted (focused on products, services, communication, processes);
- Specifications on digital inclusivity;
- Localization: geographical indication of the project;
- URL: link to an official source for further details.

These entries allowed to effectively map the selected projects, making the information comparable and easily accessible thanks to filter searches (e.g., entry, categories, keywords, etc.).

Collection of Case Studies⁵

The research was conducted using various methodological approaches, aiming to identify only real and already implemented projects. In some cases, the research was carried out directly online through official sites, cultural platforms, and digital archives to locate existing projects, while in others, hypotheses were formulated about potential case studies based on preliminary research and prior knowledge,

⁵ The complete set of case studies is available in Annex 2.

subsequently verified through primary sources. In other instances, case studies were extracted from scientific reports and articles published on academic platforms. This diversified approach has allowed for the creation of a wide and varied database.

Analysis of Case Studies

Once the database was populated with basic information on each case study, such as the type of heritage (cultural, natural, or both) and a brief description of the project, a more detailed analysis was conducted focusing on two key elements (Figure 1).

Inclusivity dimensions and specifications: each case study was examined to understand how it addresses inclusivity. This included an assessment of equality, diversity, and inclusion dimensions, identifying whether the project emphasizes equitable access for all, representation of diverse groups, or how social inclusion is promoted. The specifications collected allowed for a description of how these aspects were integrated into the adopted solutions, providing a clear picture of the design strategies implemented.

Digital inclusivity and specifications: Another area of analysis focused on the digital solutions employed in the case studies. These were classified based on their nature: product-centered solutions (e.g., applications, devices), services (e.g., personalized digital experiences), communication (e.g., informational or interactive platforms), or systemic processes (e.g., integrated approaches involving multiple interconnected elements). For each approach, technical and operational specifications were identified, evaluating how each project utilizes digital tools to enhance accessibility and inclusivity.

Case Study	Heritage	Short Description	Inclusivity Dimension	Inclusivity Dimension (Specs)	Digital Inclusivity	Digital Inclusivity (Specs)	Location	URL (Source)	Image	Resources
1 3D Archeo Lab	Cultural	3D ArcheoLab uses ...	Diversity (i.e., physica...	1. Accessible museum collections...	Product-Centred	1. Offers online 3D models, ...	Italy	https://www.3...		
2 Aira	Natural	Aira is a visual guid...	Diversity (i.e., physica...	1. Use of technology to make the...	Service-Based	1. Audio descriptions of the...	Stockholm, Sweden	https://aira.io/		
3 AllTrails App	Natural	Home to the largest...	Inclusion (i.e., goal, m...	1. Wheelchair friendly natural trai...	Service-Based	1. App that shows accessibi...	USA and Canada	https://suppor...		
4 CityFriend	Cultural	Cityfriend offers a h...	EDI (All)	1. Complete accessibility for peo...	Service-Based	1. Uses digital technologies...	Italy	https://www.ci...		
5 Contrast Chec...	Other	WebAIM is actively l...	Equality (i.e., access, ...	1. It helps visually impaired peop...	Service-Based	1. App to help visual impair...	USA	https://webal...		
6 Culture Labs: r...	Cultural	This project propos...	Inclusion (i.e., goal, m...	1. Improve dialogue and commu...	Service-Based	1. User-friendly interfaces; 2...	European Union	https://recip...		
7 CyArk: 3D Sca...	Cultural	CyArk is unlocking t...	Equality (i.e., access, ...	1. Digital and free (or low cost) a...	Communication...	1. Resources are available l...	Oakland, California...	https://cyark.o...		
8 CyArk's Tapestr...	Cultural	CyArk's Tapestry is a...	Equality (i.e., access, ...	1. Provides virtual access to herit...	Communication...		Global	https://tapestr...		
9 DigiArt	Cultural	digi.Art provides di...	EDI (All)	1. Accessibility to cultural sites fo...	Product-Centred	1. Accessibility to cultural si...	Italy	https://www.d...		
10 DiveIntoHerit...	Cultural	Dive into Heritage (...)	EDI (All)	1. The initiative aims to make wo...	System-Based	1. Provides access to digital...	Arab States region	https://whc.un...		
11 Earth.fm: Natu...	Natural	The Nature Soundm...	Diversity (i.e., physica...	1. It is a completely free streamin...	Service-Based	Each recording is accompa...	Estonia, Europe	https://earth.f...		
12 Eden Project	Natural	Explore from where...	Diversity (i.e., physica...	1. Technology is used to allow in...		1. Video and audio descript...	Cornwall, United Ki...	https://www.e...		
13 Europeana	Cultural	Europeana is a digit...	Equality (i.e., access, ...	1. Ensures broad digital access to...	Service-Based		Europe	https://www.e...		
14 Experience He...	Cultural	Experience Heritage...	Equality (i.e., access, ...	1. Provides digital access to herit...	Service-Based		York, UK	https://www.ex...		
15 Google Arts a...	Cultural	Open Heritage is an...	Equality (i.e., access, ...	1. The project ensures equal acce...	Service-Based		Global (focuses on ...	https://artsan...		
16 Kimap	Cultural	The first satellite na...	Equality (i.e., access, ...	1. physical access for people with...	Service-Based	1. The app spreads informa...		https://kimap.it/		

Figure 1: Analysis of case studies through Airtable database.

Generalization of Data and Definition of Design Guidelines

The analysis of case studies allowed for the mapping of a total of 39 projects, divided into various categories of heritage and inclusivity. Among these, 30 cases relate to cultural heritage, 4 address natural heritage, 3 include both cultural and natural elements, while 2 cases have been classified as 'other types of heritage' due to the applicability of the technologies used in different contexts.

In terms of inclusivity dimensions, the results show that 26 case studies focus on equality, 4 adopt a diversity-centered approach, addressing the representation and valorization of different identities and cultures, 1 case study focuses on inclusion, aiming to integrate individuals typically excluded from such experiences, and 8 cases adopt an EDI approach, simultaneously addressing the dimensions of equality, diversity, and inclusion.

Regarding digital inclusivity, the findings show that 6 case studies focus on a product-centered approach, 11 cases utilize a communication-centered approach, and 21 cases employ a service-based approach, offering digital experiences that facilitate access to and enjoyment of heritage through online platforms. Finally, 1 case is characterized by a systemic approach, integrating multiple digital and organizational elements for comprehensive heritage experience management.

This distribution has provided an overview of ongoing trends and allowed us to identify replicable and successful models to integrate into future design guidelines.

Design Guidelines

After completing the analysis of the case studies, a set of guidelines aimed at providing a clear and structured framework for addressing the issue of digitizing cultural and natural heritage with an emphasis on inclusivity was developed. To ensure easy and immediate access to information, the digital platform Miro was adopted as a facilitator environment to collect ideas, gather opinions, and provide final systematization of data. This platform also enabled real-time collaboration among multiple users, allowing for seamless and efficient sharing, editing, and organizing of content.

Macro-categories

In the process of developing the guidelines, a thorough analysis of the previously examined case studies was conducted with the aim of ensuring that the guidelines were based on solid evidence. The case studies provided an important foundation from which the most recurring and relevant elements were identified. This allowed for the identification of several key macro-categories that reflect the various dimensions of accessibility and inclusivity of Cultural and Natural Heritage. The identified macro categories are:

1. Socio-cultural accessibility;
2. Physical accessibility (multi-sensory);

3. Cognitive accessibility (multi-sensory);
4. Digital accessibility (remote accessibility);
5. Economic accessibility;
6. Accessibility to enabling tools (on-site);
7. Personalized enjoyment

Design Guidelines

The analysis and categorization process into macro categories then enabled the definition of a total of 8 guidelines, each aimed at ensuring an inclusive and accessible approach. The identified design guidelines are:

DG 1. Personalized enjoyment experience.

- Active user personalization, allowing users to choose consumption modes based on their interests and preferences.
- Personalization through data collection. The experience is customized by analyzing collected data to improve access to cultural/natural heritage.

DG 2. Reducing digital barriers to remotely access cultural and natural heritage sites.

- Accessibility to cultural heritage through digital solutions that lower barriers, making content available remotely to a broad and diverse audience.
- Equitable and open access, regardless of users' economic resources or technological skills.

DG 3. Access and use of cultural content by marginalized communities.

- Promoting the inclusion of marginalized communities in the cultural heritage experience by breaking down social, economic, and cultural barriers.
- The ability to access and actively contribute to the enhancement of heritage through inclusive tools and technologies.

DG 4. Customized access and use (physical, cognitive, multisensory).

- Cultural experiences that meet different motor, sensory, or cognitive accessibility needs and allow users to independently enjoy cultural heritage.
- Through interactive and adaptive technologies, users can tailor their experience to their specific needs, improving inclusivity and accessibility.

DG 5. Integration of intangible heritage into digital platforms.

- Enhancing intangible cultural heritage, such as traditions, oral knowledge, and social practices, by using digital platforms.
- Preserving and sharing intangible elements of heritage that might otherwise be lost, integrating them into digital spaces accessible to a wide audience.
- Digital platforms allow for broader documentation and dissemination of intangible heritage, making it available globally and encouraging its transmission to future generations.

DG 6. Social interaction and community engagement in creating culturally-related contents.

- Promoting active participation of local communities and users in creating and enhancing cultural content.
- Community involvement in the documentation, interpretation, and narration of cultural heritage, making the experience more inclusive and representative of diverse voices through digital platforms and collaborative projects.

DG 7. Accessibility to natural heritage in sustainable digitization processes.

- Digitization of natural heritage with a focus on sustainability and awareness for its preservation.
- Monitoring and mapping natural environments to make them digitally accessible to a global audience, raising awareness on the importance of preserving natural heritage and the role climate change plays in its protection.

DG 8. Accessible learning pathways.

- Educational pathways accessible to all, including children and individuals with cognitive disabilities.
- Providing interactive and playful learning experiences that facilitate knowledge acquisition through adaptive and accessible tools, such as educational games and interactive digital content.
- Ensuring that users with different cognitive abilities can enjoy cultural heritage independently and satisfactorily.

To conclude, these guidelines represent an important tool for promoting an inclusive approach to the digitization of cultural and natural heritage. They aim to ensure that access to heritage is fair and open to all, regardless of physical, cognitive, economic, or technological barriers. These guidelines not only enhance heritage but also place inclusivity as a central value, contributing to building a future in which culture and nature are accessible to an increasingly broad and diverse audience.

Conclusions

The pursuit of Inclusive Heritage Design serves as a vital pathway toward recognizing and honoring our diverse cultural and natural legacies while ensuring equitable access for all. By integrating the principles of inclusivity into heritage design – ranging from enhancing accessibility to engaging marginalized communities – this part of the work developed a representative and enriched discussion that acknowledges the multiplicity of human experiences as well as the contribution performed by the design community at different levels. The research methodology, encompassing literature review, case studies, and the development of actionable guidelines, underscores the critical interplay between technology and community involvement in shaping the future of heritage conservation. Ultimately, the guidelines established in this study advocate for a collaborative, adaptive approach that prioritizes accessibility, personalization, and sustainability, thereby laying the groundwork for a more inclusive heritage landscape that resonates with past, present, and future generations.

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Studies on the Manufacturing Technologies Used for the Digital Inclusivity of Cultural and Natural Heritage⁶

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This section of the report explores the intersection of inclusive design and 3D technologies, emphasizing the necessity of cultural and social shifts alongside procedural changes in fostering inclusivity. Building on a redefined notion of inclusivity that transcends mere policy, it discusses how integrating 3D printing and virtual reality can substantially enhance accessibility for individuals with diverse abilities, particularly in cultural and natural heritage contexts. Through various case studies, it illustrates practical applications of these technologies. This section also underscores the importance of incorporating the perspectives of disabled individuals from the outset of design processes and advocates for technology to adhere to ethical standards, ultimately positioning inclusive innovation as a means of enriching cultural experiences for all.

Inclusive Design and 3D Technologies⁷

Innovation is any change (not only technological)
based on knowledge (not only scientific)
that generates value (not only economic).
- Definition of *Innovation*. COTEC Foundation

An adaptation of the COTEC Foundation's definition of innovation can apply to inclusivity:

⁶ All authors have contributed to the production of this work; however, the writing of the various sections is attributed as follows: '*Inclusive Design and 3D technologies*' to Beatriz Rayón Viña & Duna Martínez del Barrio; '*Additive Manufacturing*' to Ramón Rubio García; '*Case Studies of Best Practices*' to Silvia Maria González Fernández. Where not expressly stated, the other sections are equally attributed to the authors.

⁷ A longer, completer and more detailed version of this work is available in Annex 3.

Inclusivity is any change (not only procedural) based on understanding (not only theoretical) that generates value (not only economic).

Inclusivity goes beyond policies, involving cultural shifts, attitudes, and everyday practices that create an inclusive environment. It requires active engagement with diverse communities to foster a deeper understanding of different perspectives and needs. Our aim is to start our process by asking: how, what, and for whom? We are based on the premise that the value of inclusiveness transcends economics, bringing social, cultural, and emotional benefits. It helps people pursue their own project of a *good life*⁸, while reconsidering how individual projects may affect others.

Combining inclusive design principles with 3D technologies offers a powerful tool for closing gaps between people of different abilities. For example, 3D-printed models enhance accessibility for individuals with print disabilities or those who are haptic learners, offering affordable, hands-on ways to interact with objects that may otherwise be inaccessible due to size, rarity, or danger (Holloway, 2024). These models can be optimized for touch reading and inclusion by simplifying details and incorporating tactile features and contrasting colors for those with visual impairments (Holloway, 2024). Embracing diverse abilities across cultures broadens our understanding of valuable skills and capabilities, encouraging inclusive design that reflects and respects this diversity.

Disabilities can affect vision, movement, cognition, communication, and mental health, varying in degree (e.g., blindness vs. low vision or hearing loss vs. impairment). Learning disabilities and mental health conditions also shape how individuals think, learn, and interact. The social model of disability focuses on society's role in creating barriers – through social, economic, and architectural factors – rather than seeing disability as an inherent limitation. Disability culture, in contrast to traditional views, celebrates disability as part of identity and community, promoting inclusion, respect, and equality. Inclusive design should focus on the needs and perspectives of disabled people from the start, involving them in every stage of the process. Involving potential stakeholders ensures that their voices are heard and results in more accessible, empowering solutions.

Cultural and Natural Heritage through 3D Technologies

By combining inclusive principles with 3D technologies, we can empower individuals while promoting respect, equality, and an appreciation for diverse abilities across cultures. 3D printing offers various ways to incorporate touch and other non-visual senses into cultural experiences, making cultural heritage more accessible to people with learning disabilities, children, the elderly, or those who are blind or visually impaired. This approach allows for a more complete understanding of

⁸A longer, more detailed version of this text can be found in Annex 4. The Aristotelian concept of the 'good life' (or eudaimonia) refers to a life of flourishing and fulfillment, achieved through the practice of virtue and the use of reason in accordance with one's true nature. For a deeper and broader concept see: <https://plato.stanford.edu/entries/ethics-virtue/#EudaVirtEthi>

cultural heritage, introducing a new way of ‘seeing’ culture by integrating multisensory elements (Echavarria & Samaroudi, 2019; Hewitt, 2015).

The use of 3D technologies extends beyond individual artifacts to broader areas of cultural preservation, including both tangible and intangible cultural heritage (TCH and ICH) (Skublewska-Paszkowska et al., 2022). A notable example is the *Virtual Ganjali Khan Project*, which applies 3D scanning and immersive virtual reality (VR) technologies to digitally preserve the Ganjali Khan Complex in Kerman, Iran. This project aims to ‘digitally preserve, expand access to, and develop new scholarly tools for studying the Ganjali Khan Complex’ by creating ‘high-fidelity 3D models that will be used to build immersive virtual reality (VR) experiences of the Complex’ (Bozorgi & Lischer-Katz, 2020, p. 45). These immersive tools allow users to virtually ‘walk through’ the site, providing an experience that is both proportionally accurate and interactive (Bozorgi & Lischer-Katz, 2020). Such technologies not only make heritage elements more accessible – ‘allow[ing] access to the cultural heritage elements that are difficult to reach in the real world’ (Skublewska-Paszkowska et al., 2022, p. 2) – but also offer new insights into cultural studies through the combination of audiovisual and 3D techniques.

This approach fosters a deeper understanding of heritage across diverse audiences while helping to preserve and transmit it for future generations. True inclusivity requires active participation and the celebration of diversity, rather than passive acceptance. It ensures that these innovations provide equal access to all individuals, regardless of their abilities. Technologies like 3D printing and virtual reality (VR) offer new ways to make natural heritage accessible without causing harm. They are especially valuable for remote, sacred, or fragile environments that must be protected while still being shared with the public. For instance, remote communities in natural reserves with rare geological or biological features are often off-limits for preservation reasons. Using 3D printing, these natural wonders can be recreated as detailed tactile models or VR experiences. National parks could, for example, offer 3D-printed replicas of unique formations in visitor centers, making nature accessible to all, including people with disabilities. This “virtual tourism” not only promotes accessibility but also helps preserve these sites by reducing physical wear and tear caused by mass tourism.

Epistemic Knowledge, Ethical, and Societal Responsibility

Understanding how we acquire knowledge – our epistemic knowledge – is key to this study. It is not just about what we know, but about how the methods we use shape that knowledge and define its boundaries. This process is crucial in collaborative innovation, where shared ‘epistemic objects’, like 3D models, guide exploration and facilitate idea generation (Riikonen et al., 2018). These objects evolve with input from participants, helping teams visualize concepts, test ideas, and drive creativity.

In design processes, shared epistemic objects allow diverse groups to engage deeply with ideas, promoting inclusivity and ensuring that technological advancements uphold ethical standards across cultures. This approach shifts our understanding of disability, as the social model suggests that disabilities emerge not from individuals but from the barriers created by society (Velázquez, 2009). 3D designs and inclusive projects can challenge these societal barriers, helping redefine the concept of disability. Rather than normalizing individuals, they focus on transforming exclusive environments.

As Toboso Martín (2021) notes, abilities are shaped not only by our biology but also by our sociocultural context, highlighting the need to rethink how we value and support different abilities. For example, 3D-printed replicas of cultural artifacts can serve as educational tools and exhibits, making cultural heritage accessible to all. By involving communities and accessibility experts in such projects, we honor diverse cultures while promoting fairness and inclusivity. This commitment to accessibility and cultural preservation empowers individuals and fosters a shared human experience.

Technology, driven by human creativity, reshapes the world by envisioning alternatives to the *status quo* (Friedman & Hendry, 2019). In this process, ignoring values is no longer acceptable. Technology must integrate moral and ethical considerations to benefit society. For example, in cultural heritage, 3D technologies can preserve and promote artifacts and traditions, offering new ways to engage with history while promoting inclusivity and accessibility. Communities can use these technologies to revive endangered crafts or recreate fragile artifacts, enhancing cultural understanding and democratizing access to shared heritage.

Applying *Value Sensitive Design* (VSD) ensures that projects respect ethical standards by involving both direct and indirect stakeholders. This makes 3D technologies more than just tools – they become transformative mechanisms for inclusion and conservation, balancing human values with innovation. VSD bridges past and present, preserving not just objects but collective memory and identity. It aligns technological advancements with ethical responsibility, promoting accessibility, sustainability, and cultural relevance. By addressing ‘value tensions’ and focusing on human flourishing, VSD fosters socially responsible solutions that enhance both the moral and technical aspects of design (Friedman & Hendry, 2019).

Digitization: From the Real to the Virtual

There are different technologies that allow the capture of a point cloud (digital format) from a physical model. Some of them are listed below:

- Laser scanning: A laser beam hits the surface, and a device captures the rebound of that light. This way, the scanner can calculate the distance of that specific point and position it in a digital XYZ space. Repeating this process thousands of times generates the point cloud.

- Photogrammetry: Dozens of photos are taken from different viewpoints around the real model to be scanned. Then, specific software combines all these photos (searching for specific points with the same color) and generates the point cloud. It is a more economical process but with lower resolution than laser scanning.
- Structured light scanning: Similar to laser scanning, but instead of projecting a point of light, a light pattern (a set of stripes or grids) is projected onto the real model. A series of cameras capture how the pattern is deformed when it hits the model. Software collects this information and generates the virtual model.

Once the digital model is obtained, it can be edited in modeling software and introduced into a specific scene. Unity is currently one of the most widely used platforms for this process. These types of modeling programs can generate a file to be viewed in browsers or virtual reality glasses, devices that allow users to visualize and interact with the model. The applications of this process are vast and particularly interesting for the preservation of cultural and natural heritage. For instance, museums can preserve their artworks by having a digital copy used for dissemination purposes. Territories can also use this technology to showcase their natural heritage. For example, an area of archaeological interest could be scanned and then explored virtually with VR glasses, without the need for physical presence.

Key VR Standards

The following are the most relevant standards related to virtual reality:

- ISO/IEC 18039:2014. Information technology – Definition and visualization of virtual environments.
- ISO 9241-910:2011. Ergonomics of human-system interaction – Part 910: Framework for tactile and haptic interaction.
- ISO 9241-411:2020. Ergonomics of human-system interaction – Evaluation methods for the design of physical input devices.
- ISO/IEC 23005 (MPEG-V) Series. Information technology – Media context and control – Part 1: Architecture.
- ISO/IEC 14772-1:1997 (VRML). Information technology – Computer graphics and image processing – The Virtual Reality Modeling Language (VRML).
- ISO/IEC 23090-2:2021 (MPEG-I). Information technology – Coded representation of immersive media – Part 2: Omnidirectional media format.
- ISO/TS 9241-940:2020. Ergonomics of human-system interaction – Evaluation of tactile and force-feedback devices.
- ISO 18529:2000. Ergonomics – Ergonomics of human-system interaction – Human-centered lifecycle process descriptions.

Additive Manufacturing

Additive manufacturing is a set of technologies that produce three-dimensional objects by adding material, most often in a layer-by-layer material addition process. In the beginning, in the mid-1980s, its application was limited to prototype manufacturing. However, in recent decades, the evolution of materials and improvements in technologies have allowed its application to a multitude of industrial sectors. Additive manufacturing could be considered another production technology, with its advantages and disadvantages compared to other traditional processes. Its strengths are short production runs, geometric complexity, and mass customization.

These three attributes have been exploited by a large part of the industry, and it is important to highlight that the spread of this technology in recent years coincides with a time when many technologies, not just additive ones, are being used by consumers themselves to create new products.

Characteristics of Additive Manufacturing

Additive manufacturing has three main characteristics: complex geometry, short production runs, and customization. Whenever at least one of these is present, additive manufacturing is a process to consider. Additive manufacturing can be used in any situation, but it is when all three characteristics are combined that complete manufacturing freedom is achieved, fully leveraging the technology.

Furthermore, it is important to note that additive technologies have coincided with a democratization movement they have themselves fostered, such as through the maker movement. This access to technology has often allowed the customer to become the product designer, transforming the consumer into a prosumer.

Geometric Complexity

Additive manufacturing allows the construction of complex geometries. This represents a significant advantage over formative or subtractive technologies, which do not offer the freedom of shapes that additive manufacturing does. As will be seen in later chapters, this does not mean that any design or concept can be manufactured, as the printing machines will impose their own restrictions. However, generally, the designer will not encounter a bottleneck for their designs in additive processes.

In these technologies, greater geometric complexity of a part does not imply an increase in cost. In traditional manufacturing processes, such as machining, a complex geometry is achieved through manufacturing strategies, fixtures, and costly custom tooling. Therefore, increasing the formal complexity of the product also often increases the complexity of the manufacturing process and the cost relationship between geometric complexity and unit manufacturing cost.

Paradoxically, a complex geometry can result in cost savings in the manufacturing process, as it often involves less material use and reduced manufacturing time compared to traditional technologies. Therefore, additive technologies may not only provide a cost advantage for certain geometries but also become the only technology capable of manufacturing certain shapes that have not been explored due to the restrictions of traditional processes. Design advantages should be studied and trained by engineers and designers, depending on which additive technology is employed.

Short Production Runs

Additive manufacturing offers the possibility of producing the required number of parts at a given time (manufacturing on demand). This contrasts with traditional manufacturing, which requires molds and tooling, leading to long production times and high fixed costs. This necessitates the production of a large number of units to amortize all the costs incurred during production.

Moreover, both the time and cost associated with traditional production are incompatible with agile product development management. The launch of a new product requires a series of stages of considerable duration, whereas current trends in product development suggest agile process management. Developing prototypes or short runs that can be quickly validated in the market and improved before final distribution reduces the failure rate of the final product. The choice of additive manufacturing over traditional technologies like machining or injection molding is often made after a cost analysis.

Comparing manufacturing technologies in terms of cost is complex due to the large number of parameters that must be considered, from inventory and transportation costs to the orientation of the part in the machine, which can increase the cost per part by up to 160%. Technological advancements in recent years have allowed machines to produce an increasing number of parts. For example, HP's MJF technology is ten times faster than SLS technology and a hundred times faster than FFF technology, while Carbon 3D's CLIP technology is almost a hundred times faster than DLP technology, with new technologies emerging with even higher speeds (e.g., Spry Build's CPWC).

There is therefore a trend in additive manufacturing towards large-scale production, aiming to compete with plastic injection molding and evolving from 'rapid prototyping' to 'rapid high-volume manufacturing'. The emergence of additive manufacturing centers with automated production management is accelerating this process.

Customization

The final characteristic of additive manufacturing is its ability to customize products. In recent years, there has been an explosion of options for almost any product imaginable, known as mass customization. Mobile phones, jewelry, industrial parts,

clothing, and medical implants are just a few examples of product families that have greatly expanded their range of final products due to customer demand.

Until the 19th century, products were characterized by their heterogeneity and a limited number of units of each type, being predominantly handcrafted. The advent of the Industrial Revolution brought about specialization in labor, significantly increasing the number of units but reducing the number of options, marking the era of mass production.

As consumers demand high volumes of customized products, business models based on mass production are giving way to those based on mass customization. Mass customization is the ability to offer personalized products, individually designed in medium or low volumes, at a relatively low cost. Initially, this may seem like a combination of two opposing concepts: production and customization. However, technologies like additive manufacturing allow the merging of the advantages of both.

Additive manufacturing does not distinguish between customized or standardized products. The cost increase is passed on to the designer who must customize, but the involved cost is much lower than the added value of the final product. The medical implant sector is the most established in the market of all those related to additive manufacturing, where customization has enabled the creation of high-value-added implants.

Additive Manufacturing Standards

Nowadays, it is difficult to find an industry that is not regulated to some extent by standards. These standards facilitate interoperability between existing products and services, consequently reducing costs and time-to-market. In turn, they offer protection and security to customers and suppliers.

The ISO TC 261 Additive Manufacturing committee, along with its European counterpart CEN/TC 438 Additive Manufacturing, are responsible for developing standards related to additive manufacturing. According to UNE, these committees are in charge of standardizing processes, test procedures, quality parameters, and supply agreements related to additive manufacturing.

Key Additive Manufacturing Standards

ISO/ASTM Standards

- ISO/ASTM 52900:2021. Additive manufacturing – General principles – Terminology.
Description: Provides a set of terms and definitions to standardize language across the additive manufacturing industry.
- ISO/ASTM 52901:2017. Additive manufacturing – General principles – Requirements for purchased AM parts.
Description: Specifies requirements for the quality, technical data, and processes for acquiring parts made by additive manufacturing.

- ISO/ASTM 52902:2019. Additive manufacturing – Test methods – Guide for characterization of AM materials.
Description: Outlines methods for characterizing materials used in additive manufacturing processes.
- ISO/ASTM 52903-1:2020. Additive manufacturing – Material extrusion-based AM – Part 1: Feedstock materials.
Description: Provides principles and terminology specific to material extrusion-based additive manufacturing.
- ISO/ASTM 52904:2019. Additive manufacturing – Process characteristics and performance – Practice for metal powder bed fusion.
Description: Establishes requirements for the qualification of metal powders used in powder bed fusion processes.
- ISO/ASTM 52910:2018. Additive manufacturing – Design – Requirements, guidelines, and recommendations.
Description: Offers guidelines and principles for designing parts to be produced using additive manufacturing technologies.
- ISO/ASTM 52911-1:2019. Additive manufacturing – Design – Part 1: Laser-based powder bed fusion of metals.
Description: Provides design recommendations specific to laser-based powder bed fusion of metals.

ISO 17296 Series

The ISO 17296 series also plays an important role in additive manufacturing:

- ISO 17296-1:2016. Additive manufacturing – General principles – Part 1: Terminology.
Description: Defines terms and concepts related to additive manufacturing.
- ISO 17296-2:2015. Additive manufacturing – General principles – Part 2: Overview of process categories and feedstock.
Description: Provides an overview of different additive manufacturing processes and the materials used.
- ISO 17296-3:2014. Additive manufacturing – General principles – Part 3: Main characteristics and performance measures.
Description: Describes the main characteristics and performance metrics for additive manufacturing processes.
- ISO 17296-4:2014. Additive manufacturing – General principles – Part 4: Test methods and quality assurance.
Description: Details methods for testing and ensuring the quality of additively manufactured products.

These standards provide a comprehensive framework for terminology, process requirements, material characterization, design principles, quality management, and testing in the field of additive manufacturing. They are essential for ensuring consistency, quality, and safety in additive manufacturing operations.

Case Studies of Best Practices⁹

By mapping the case studies according with the inclusion criteria, we can observe how different projects contribute to making cultural and natural heritage more inclusive and accessible. The alignment outlines successful strategies and models that can guide future efforts in digitizing and conserving heritage, ensuring that it is enjoyed by a wider and more diverse audience.

The provided Table 4 highlights and analyzes 19 mapped case studies that prioritize inclusivity and accessibility when digitizing and 3D printing cultural and natural heritage. Each case study is analyzed to focus on promoting Equality, Diversity, and Inclusion through various strategies. In the following section, It is explained the mapping and provided a review of the case studies.

In the table below (Table 4) we can analyze the cases with the following criteria.

Table 4: 19 mapped case studies (Source: own elaboration).

Type of Heritage	Project Name	Inclusivity Dimension	Digital Inclusivity and Specificat.	Location	Objective	Equipment	Beneficiary	Short Description
Cultural	Case Study 1. Michael Hansmeyer's opera for The Magic Flute	Not specified	Product-centered solution using stereolithography 3D printing (SLA)	Brussels, Belgium	To recreate The Magic Flute scene and ephemeral representation	Stereolithography 3D printing (SLA)	Factum Arte, theater audience	Use of advanced 3D printing techniques to create intricate stage designs for the opera at Théâtre Royal de La Monnaie de Munt.
Cultural	Case Study 2. Calatrava Turning Torso	Social/Cultural	Product-centered solution using 3D printing to create a physical model	Malmö, Sweden	Tribute to Calatrava through a physical model of the building	BCN3D Sigma 3D Printers	Residents, public audience	Creation of a 3D-printed model of Calatrava's Turning Torso as a tribute, symbolizing human motion.
Cultural / Natural	Case Study 3. Buddhas of Bamiyan Reconstruction	Involvement of international organizations promoting inclusivity and Equality	Product-centered solution using 3D printing and digital reconstruction	Bamiyan, Afghanistan	To restore the Buddhas destroyed by the Taliban	ProJet 3D printer with ColorJet® technology	Afghan people, global heritage community	Digital and physical reconstruction of the destroyed Buddhas using historic documentation and 3D printing, led by UNESCO and ICOMOS.

⁹ All references and a more visual version of this work is available in Annex 4.

Social / Cultural	Case Study 4. Kakuma Refugee Camp Project	Addresses are inclusive by improving living conditions for refugees. Diversity and Inclusion	Systemic processes using advanced fabrication methods (6-axis robotic arm)	Kakuma Refugee Camp, Kenya	Education program focusing on security and privacy in design	6-axis robotic arm	Refugees in Kakuma Camp	Designing and constructing improved educational and living spaces using advanced architectural techniques for refugees.
Cultural	Case Study 5. Uomo barbuto di Vado all'Arancio	Promote accessibility for the visually impaired. Diversity and Inclusion	Product-centered solution using 3D printing and tactile models	Massa Marittima, Italy	Create an accessible path for blind people through audio-tactile works	Multi-image photogrammetry, TOF laser scanner, 3D printers	Visually impaired individuals, GaMHer Project	Production of tactile replicas of archaeological findings to make cultural heritage accessible to blind visitors.
Cultural	Case Study 6. Accessibility Initiatives at Madrid Naval Museum	Emphasizes equitable access and social inclusion. Equality, Diversity and Inclusion	Product-centered solutions (3D Braille devices), services (audio guides), communication (accessible apps)	Madrid, Spain	Develop 3D printed Braille devices for visual and cognitive deficiencies	3D printers	Tourists with disabilities	Implementation of tactile stations, accessible apps, and specialized activities to enhance museum accessibility for visitors with disabilities.
Cultural	Case Study 7. Bespoke Bodies: The Design and Craft of Prosthetics	Represents diverse groups and promotes social inclusion. Diversity, equality, inclusion	Product-centered solutions (3D-printed prosthetics), interactive services	Kansas City, Missouri, USA	Explore and showcase the evolution and innovation in prosthetic design	3D prototypes	People with disabilities, museum visitors	Exhibition featuring stories and innovations in prosthetic design, including interactive VR stations and 3D-printed prototypes.
Innovation / Other	Case Study 8. Philippines' Lewis Grand Hotel 3D-Printed Suite	Not specified	Systemic process using 3D printing in construction	Angeles City, Philippines	Build a 3D-printed hotel suite cheaper and faster	Ecological materials, 3D printers	Tourists	Construction of a fully operational hotel suite using 3D printing technology, showcasing innovation in sustainable building methods.
Cultural	Case Study 9. Replica of Nike of Samothrace	Enhances cultural accessibility. Equality, inclusion	Product-centered solution using 3D printing and robotic carving	Samothrace, Greece	Create an exact replica of the statue for public display	3D printer, marble robotics machines	Local government, public audience	Creation of a marble replica of the iconic statue using 3D digitization from the Louvre, enhancing cultural heritage access.

Other / Assistive Technology	Case Study 10. Camera 2C3D	Promotes inclusivity for the visually impaired. Diversity, Inclusion	Product-centered solution (camera with tactile feedback)	Not specified	Help blind people perceive objects through tactile imaging	3D printers	Blind and visually impaired individuals	Development of a camera that creates tactile representations of photographs, allowing blind users to "feel" images.
Natural	Case Study 11. 3D Rosetta Stone by British Museum	Enhances global accessibility and engagement. Equality and Inclusion	Communication through digital platforms (online 3D model)	London, UK	Enhance accessibility and engagement with the Rosetta Stone	Digitization tools, online platforms	Global public, researchers	The British Museum uploaded a high-resolution 3D model of the Rosetta Stone to Sketchfab, allowing virtual access worldwide.
Innovation / Other	Case Study 12. Apis Cor 3D Houses	Potential to address housing accessibility, Equality	Systemic processes using mobile 3D construction printing	Various locations	Build economical 3D-printed houses in 24 hours	Apis Cor mobile 3D printer	Homebuyers, construction industry	Apis Cor uses mobile 3D printing technology to construct entire houses quickly and affordably, revolutionizing traditional building methods.
Social	Case Study 13. Thinking Huts' 3D-Printed Schools in Madagascar	Promotes equitable access to education. Equality and Inclusion	Systemic processes (3D printing in school construction)	Madagascar	Create schools to connect communities and improve education	3D printers, cement mixture	Children, local communities	Construction of 3D-printed schools based on sustainable designs to enhance educational infrastructure in remote areas.
Cultural	Case Study 14. Edible Met by Medialab at The Met	Enhances visitor engagement through multisensory experience	Product-centered solution (3D-printed edible art)	New York City, USA	Create 3D edible prints of cultural heritage pieces	3D food printers	Museum visitors	Innovative project creating edible 3D-printed replicas of art pieces to provide a multisensory museum experience.
Cultural	Case Study 15. Lanterns Project in Belfast	Not specified	Product-centered solution (3D-printed lighting installations)	Belfast, Northern Ireland	Illuminate streets with 3D-printed orbs reflecting maritime heritage	Ultimaker S5 3D printer	Citizens, tourists	Urban lighting project creating a floating ocean of 3D-printed orbs to enhance public spaces and reflect local heritage.
Cultural	Case Study 16. VR Reconstruction of Pompeii's House of the Greek Epigrams	Enhances educational accessibility. Equality and Inclusion	Services using VR and eye-tracking technologies	Pompeii, Italy	Study perception in Roman spaces using VR and eye-tracking	VR headsets, eye-tracking, GIS, 3D software	Researchers, students, visitors	Use of VR and eye-tracking to understand ancient Roman architecture's influence on social identity and sensory

Cultural	Case Study 17. The VENUS Project's Virtual Exploration of Underwater Sites	Promotes accessibility to inaccessible sites. Equality and Inclusion	Services using VR, photogrammetry, and sonar mapping	Port-Miou C wreck, Marseille, France	Create immersive environments for underwater site exploration	VR technology, sonar, photogrammetry	Archaeologists, public audience	Virtual reconstruction of underwater archaeological sites, allowing virtual dives and promoting digital preservation of heritage experiences.
Cultural	Case Study 18. Virtual Reconstruction of Fano Roman Theatre	Enhances cultural education and accessibility. Equality and Inclusion	Services using AR/VR platforms and 3D modeling	Fano, Italy	Virtually reconstruct lost Roman architecture for educational use	TLS, 3D modeling software, AR platforms	Historians, students, tourists	Digital reconstruction of the Fano Roman Theatre using AR/VR technologies, making it accessible for educational purposes.
Natural	Case Study 19. Virtual Tours of Ayutthaya's Heritage Sites by CyArk	Enhances global accessibility and education. Equality and Inclusion	Services using VR platforms and photogrammetry	Ayutthaya, Thailand	Digitally preserve and provide immersive virtual tours of heritage sites	3D modeling, VR headsets, photogrammetry	Scholars, tourists, global audience	Creation of immersive virtual tours of Ayutthaya's historical sites, promoting global engagement and preservation.

Subsequently, a brief adapted description is presented of the importance of 3D printing and new technologies applied to inclusion, diversity, and accessibility in each analyzed case study.

Case Study 1 – Michael Hansmeyer's Opera for The Magic Flute.

This project showcases advanced 3D printing for stage design in an opera. Even though it is innovative, it does not specifically address inclusivity or accessibility as defined by the previous dimensions.

Case Study 2 – Calatrava Turning Torso.

The creation of a 3D-printed model of Calatrava's Turning Torso serves as a tribute to the architect's work. Although it involves digital fabrication, it does not specifically address issues of inclusivity, accessibility, or engage with the design guidelines provided.

Case Study 3 – Buddhas of Bamiyan Reconstruction.

The project digitally reconstructs the destroyed Buddhas, making this significant cultural heritage accessible globally through digital platforms. It preserves intangible cultural heritage by integrating historical and spiritual significance into a digital format, ensuring that the heritage is not lost despite physical destruction. The digital reconstruction allows global audiences to Access and learn about the Buddhas remotely, reducing geographical barriers.

Case Study 4 – Kakuma Refugee Camp Project.

The project addresses the needs of refugees—a marginalized community—by improving living and educational spaces. It incorporates customized designs to

meet diverse needs within the camp, and enhances educational opportunities through accessible learning environments, promoting inclusion and empowerment.

Case Study 5 – Uomo barbuto di Vado all'Arancio.

By creating tactile replicas of archaeological findings, the project enables visually impaired individuals to access and experience cultural heritage through touch. This multisensory approach caters to diverse cognitive and physical abilities, promoting inclusivity.

Case Study 6 – Accessibility Initiatives at Madrid Naval Museum.

The museum offers digital solutions like accessible apps and audio guides, reducing barriers to remote access. It provides Braille devices and tactile stations, accommodating visitors with various physical and cognitive needs, ensuring that the museum experience is inclusive.

Case Study 7 – Bespoke Bodies: The Design and Craft of Prosthetics.

The exhibition represents diverse groups, including individuals with disabilities, promoting their stories and contributions. It showcases customized prosthetics, highlighting personalized solutions for accessibility. Interactive exhibits provide educational content accessible to a wide audience.

Case Study 8 – Philippines' Lewis Grand Hotel 3D-Printed Suite.

This project demonstrates innovation in construction using 3D printing technology. However, it does not explicitly focus on inclusivity or accessibility aspects outlined.

Case Study 9 – Replica of Nike of Samothrace.

By creating a local replica of the famous statue, the project enhances access to cultural heritage for those unable to visit the original at the Louvre. It uses digital technology to preserve and share cultural heritage within the community, integrating intangible aspects like historical significance into the local context.

Case Study 10 – Camera 2C3D.

The development of a camera that produces tactile images enables blind and visually impaired individuals to perceive photographs through touch. This innovative device caters to diverse sensory needs, promoting inclusion through technology.

Case Study 11 – 3D Rosetta Stone by British Museum.

By uploading a high-resolution 3D model of the Rosetta Stone online, the British Museum makes this important artifact accessible worldwide. The digital preservation integrates the artifact's historical and cultural significance into a platform accessible to all.

Case Study 12 – Apis Cor 3D Houses.

The project introduces sustainable 3D printing construction methods that can make housing more affordable and environmentally friendly. While it focuses on innovative building techniques, it does not directly address access to natural heritage or inclusivity according with the criteria of inclusivity or equality.

Case Study 13 – Thinking Huts' 3D-Printed Schools in Madagascar.

The project provides educational facilities to marginalized communities in Madagascar, enhancing access to education. It employs sustainable 3D printing methods, reducing environmental impact. By building schools, it creates accessible learning pathways for children.

Case Study 14 – Edible food by MediaLab.

The project offers a personalized and multisensory museum experience by creating edible 3D-printed replicas of art pieces. This approach engages multiple senses and caters to diverse visitor preferences, enhancing accessibility and enjoyment.

Case Study 15 – Lanterns Project in Belfast.

This urban lighting project involves community engagement in designing and creating cultural content. By reflecting local heritage through collaborative design, it fosters social interaction and inclusivity within the community.

Case Study 16 – VR Reconstruction of Pompeii's House of the Greek Epigrams.

The use of VR and eye-tracking technology allows for personalized virtual experiences of ancient Roman spaces. It enhances remote access to heritage sites, making them available to a wider audience. The project provides customized, multisensory engagement, accommodating different user needs.

Case Study 17 – The VENUS Project's Virtual Exploration of Underwater Sites.

By creating virtual explorations of underwater archaeological sites, the project allows access to otherwise inaccessible heritage. It digitally preserves underwater heritage, integrating it into accessible platforms. The project promotes sustainable digitization by minimizing physical intervention in fragile underwater environments.

Case Study 18 – Virtual Reconstruction of Fano Roman Theatre.

The digital reconstruction makes the lost Roman theatre accessible remotely. It preserves and integrates historical architecture into digital platforms. The project provides educational content through AR/VR technologies, enhancing learning opportunities.

Case Study 19 – Virtual Tours of Ayutthaya's Heritage Sites by CyArk.

The project offers immersive virtual tours of Ayutthaya's historical sites globally, enhancing accessibility. It digitally preserves and shares cultural heritage, integrating intangible aspects into the experience. By sharing cultural narratives, it enhances community engagement and allows for broader social interaction.

Projects such as the Edible food and the VR Reconstruction of Pompeii offer personalized experiences, enabling users to interact with heritage based on their interests and preferences. Digital technologies are used in projects like the Buddhas of Bamiyan Reconstruction and the British Museum's 3D Rosetta Stone to make heritage accessible remotely and overcome geographical and physical barriers. Marginalized groups can access cultural content and educational facilities more easily thanks to initiatives like the Kakuma Refugee Camp Project and Thinking Huts' 3D-Printed Schools, which address their needs. Another projects, like the Uomo barbuto di Vado all'Arancio and Camera 2C3D focus on creating customized solutions that cater to diverse physical and cognitive abilities, promoting inclusivity through multisensory engagement.

The integration of intangible heritage also play an important role: Digital preservation projects such as the virtual reconstruction of Fano Roman Theatre and the Virtual Tours of Ayutthaya integrate intangible cultural elements into accessible digital platforms, ensuring accessibility of cultural narratives. Community engagement is also a social criteria to enhance culture. The Lanterns Project in Belfast and CyArk's virtual tours encourage community participation and engagement, reflecting local heritage and fostering social inclusion. Another project

that aids in maintaining digitalization processes is the Venus Project, which encourages environmental awareness and preservation of heritage. Finally, educational initiatives within projects like the Kakuma Refugee Camp and Bespoke Bodies provide accessible learning opportunities, enhancing knowledge acquisition for diverse audiences.

Conclusions

The integration of inclusive design and 3D printing technologies to improve accessibility for people with various disabilities is a very promising field. Making cultural and natural heritage more accessible through tactile and interactive experiences, enabling people with visual impairments, cultural diversity or other learning styles and differences to interact more deeply with cultural artifacts and environments is inclusive and valuable for all people equally. The approach goes beyond technology and focuses on removing social and physical barriers to make technology work for people.

3D technologies, as exemplified by the cases collected, can be successfully used for the purpose of this project. Virtual Reality (VR) and 3D printing are promising technologies for ENRICH. These tools offer immersive and tactile experiences that can help bridge the gap between individuals and cultural heritage, particularly for those with disabilities. By creating more engaging, accessible, and interactive environments, these technologies contribute to the overall goal of fostering inclusivity. They enable a richer understanding of cultural heritage, making it more relatable and engaging for people of all backgrounds and abilities.

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Dramaturgical Impacts of Digital Technologies and Inclusive Design Methods for Natural and Cultural Heritage Storytelling¹⁰

Rebecca Rouse

This section of the report focuses on issues of dramaturgical (meaning-making) impact as well as inclusive design methods for natural and cultural heritage storytelling. Digital technologies are pervasive in heritage work today, from online ticketing systems, to collections databases, to visitor-facing websites and applications. Increasingly XR technologies such as augmented, virtual, and mixed reality are implemented to create interactive storytelling experiences at cultural and natural heritage sites, and to enable virtual visits remotely. Both the nature and particular affordances of XR technologies themselves as well as the design methods used to develop such projects impact the meaning-making experience for their end users. The unique qualities of XR technologies from a dramaturgical perspective will be addressed first, and then a discussion of design methods will follow. Finally, a series of recent case studies are shared with particular emphasis on both design method and story experience.

Affordances of XR Technologies in Heritage Contexts

Digital technologies are ubiquitously integrated in heritage work today across a wide range of contexts from behind-the-scenes to those directly shaping the visitor encounter. Increasingly, new interactive and immersive technologies such as virtual, augmented, and mixed reality (now often referred to collectively as XR

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technologies) are being implemented in heritage contexts. Uses of digital technologies for heritage, including these new media, have been extensively researched from a range of interdisciplinary perspectives including museum studies (Parry 2010), digital humanities (Cameron and Kenderdine 2007), architecture and simulation (Liestøl and Morrison 2013), performance studies and human-computer interaction (Benford and Giannachi 2011), human-centred computing (Barba and Macintyre 2011), education (Klopfer 2008), interactive narrative and film (Reyes 2024), as well as media studies and design (Rouse et. al. 2015).

Key qualities emerge in these discussions regarding the affordances of these various new media, which can be leveraged for heritage storytelling. Affordances include qualities common to all digital media (i.e, ability to hyperlink and create nonlinear narratives, the encyclopaedic scope of digital technologies, potentials for responsively, and aspects of performativity). Affordances more specific to each different medium are also discussed, such as augmented or mixed reality's layering capacity and potentials in terms of site-specific experience design, and virtual reality's capacity for visual and sonic immersion, as a particular benefit in terms of simulation and spatial storytelling. Across all uses of digital technologies tensions are also noted with respect to storytelling, such as the balance between authorial control and visitor input, interactive narrative structure and meaning-making, ease of use and accessibility both on the visitor end but also in terms of development needs, lack of sustainability of the technologies and prohibitive costs, capacity for individual vs. group experience design, and specific to the heritage context tensions regarding the mandate for historical accuracy and education in contrast to the fictionalisation of simulation and entertainment.

Inclusive Design Methods for XR Technologies in Heritage Contexts

Research on design methods for digital heritage has also been underway for several years, also with increasing emphasis on methods for the inclusion of XR technologies in the heritage sphere. Inclusion can be understood broadly to refer not only to the accessibility of final products to as broad a user group as possible including those who are socially marginalised, but also to refer to the active inclusion of individuals and groups beyond the traditional design team in the design process itself. This can range from a participatory or co-design process to the literal expansion of the design team to include representatives of the needed communities as official design team members.

Broadly speaking the approach to XR design process tends to vary according to disciplinary background (Rouse and Barba 2017). Since little formalised training in XR design is available (for example, there are no exclusively XR degree programs yet), designers with arts backgrounds tend to take an opportunistic approach, while those with technical backgrounds tend to follow deterministic methods. Increasingly, issues of power and ethics in the design process have led to the development of critical design approaches (Rouse 2022), questioning of the ethics of co-called

empathy inducing claims (Rouse 2021), and a move toward community-based approaches (Fisher 2021). Particular attention has been paid to the complexities of telling the stories of others (Rouse 2019), the need for hospitality as a design value (Löfgren 2020), and issues of dark tourism as a form of exploitation (Fisher & Schoemann 2018).

Both affordances and challenges of XR and other interactive or immersive technologies in the heritage contexts are discussed below, as well as a range of methods reflected upon in application. In particular, issues of inclusion are highlighted in terms of design methods, practices, and outcomes. This series of examples are drawn from lectures presented in the first of three ENRICH project workshops, held September 25 and 26, 2024 at University of Skövde and PlayLab, in Skövde, Sweden.

Examples from Workshop 1 Lectures

Augmenting Communities Together: Digital Heritage Collaborations

This lecture provided reflections on a US-based NEH funded course, AR Design for Cultural Heritage, which Rouse developed and ran for six years at Rensselaer Polytechnic Institute in Troy, New York. This cross-listed undergrad-grad course was a project-based experience for students to work with external partners such as museums and heritage sites to prototype mobile AR experiences. Curricular and extracurricular projects were developed with a range of partners including the Rensselaer County Historical Society, the New York State Office of Historic Preservation, the Rensselaer Polytechnic Institute Library and Archives, the Rapp Road Historical Association, the City of Cohoes, and the MiSci Museum of Science and Innovation. Topics and themes of these mobile AR heritage projects included 19th century labor in wealthy industrialist homes, mid-twentieth century urban renewal, the history of the Brooklyn Bridge, stories from the era of Great Migration and ongoing African American community-building today, Native American heritage of the Mohawk Valley area, and a repositioning of Harriet Tubman as a STEM innovator using natural science knowledge such as navigation by star positioning to help others achieve freedom from enslavement.

Insights from the suite of projects discussed led to the development of an iterative co-design process grounded in authentic community connection and networking fostered over a longer-range timeline. The inclusion of multiple stakeholder groups as active participants in the process was stressed, as was the need for reaching out to experts in the content area. Openness was emphasised as a key value in the design process, since pre-determination of choices can lead to silencing of important voices who may not have been heard before, thus reducing inclusivity. A key takeaway was extended the timeline for the design process, both to allow for wider inclusion in the process from the beginning, but also to acknowledge the need to stay on and support communities through the sustaining of projects 'ongoing development.

Child Remains: An Immersive Conversation About Grief

This lecture shared insights from an MFA thesis project in collaboration with Lilla Änngården museum in Gothenburg, a house museum focused on sharing the lives of the family that lived there from the 1840s until the 1960s. Di Feola worked as an artistic researcher to develop an XR installation for the museum that created a possibility space for visitors to share about their own experiences of loss, based on the experience of the historical family and their loss of three children, as well as her own experience with child loss.

The installation took the form of a mixed reality experience with physical objects as well as VR components, and the presence of di Feola herself as a live facilitator to help guide and shape the experience for each visitor according to their interest. Methods used included site-specific design, interaction design, iteration and testing, hand-crafting of physical materials such as hand-woven rug, and using the artist's own grief experience as embodied knowledge as an ethical guide in the process. The installation was enthusiastically engaged with by many, and succeeded in creating links between the past and today for a cohesion that allows for difficult subjects (in this case child loss) to be processed together with others. Time was pointed out as a key design value for impact, in that the experience was designed for extended engagement and could not be rushed through.

Co-Creating Playable Communities with Youth in the Baltic Sea Region

This lecture reflected on a multiyear interreg-funded urban cultural planning project which ran from 2017-2021. Part of the project was focused on the use of games to make city planning accessible to youth. To achieve this, base layout Minecraft simulations of cities were created based on real geospatial data, as digital twin cities. Youth were then invited to workshops to build replica buildings and settings, providing the details for the models. As youth engaged these basic city models and worked to develop them further, several different types of emergent interaction took place, some playful and some reflective of darker cultural impulses.

For example, one group of children decided to take over the central square of a town to build a McDonalds fast food restaurant, a move that might seem to disregard the heritage of the site but reflected the reality of a recently closed McDonalds where the children used to meet and socialise. Stories of more personal heritage emerged, when a child focused on a detailed reconstruction of a public library interior, explaining the importance of this site for her immigrant family as a haven for learning new language and culture after their recent arrival. A young child reconstructed machinery at a local construction site, because his father was a worker there. Others collaborated to design a new playground. But other emergent behaviour was also noted, with some children adding Donald Trump to landscapes, or inscribing swastikas on building walls. This less pro-social behaviour can be seen as both part of the tradition in online worlds of so-called 'griefing' but also reflective of real-world political tensions.

In parallel to the Minecraft workshops, a physical board game approach was also developed, which resulted in less anti-social behaviour but was also fertile ground for young peoples' creativity. Key takeaways from this lecture included the complexity of digital worlds for heritage aims, and the utility of traditional physical media such as the board game. Time and resources were also emphasised, with reminders that while using an existing digital platform (ie, Minecraft) may sound like a compelling shortcut to developing something from scratch, it will bring with it not only its own set of constraints which may be antithetical to the project at hand, but also carries user expectations and traditions (ie., 'griefing') which may be undesirable.

Cultural Heritage and Game technologies in Skaraborg

This lecture discussed a suite of ongoing projects begun in 2015 which focus on local folklore in the Skaraborg region of Sweden. The project, titled "KLUB" (an acronym for Kira and Luppe's Bestiary) is a transmedia storytelling project across illustrated children's book which include an AR interactive app, site-specific elements which are also AR-enabled, museum installations, audiobooks, and even a physical board game. Robert Smithson's dialectic approach between site and non-site was discussed as a theoretical foundation for place-making at work in the project. Character was highlighted as a main design method, with the use of fictional characters and a fictional transmedia meta-story as frame capable of tying together the many, disparate characters and events found in local folklore in the area. In terms of partnerships and project sustainability, it was pointed out that a for-profit model may not be a good fit for telling these smaller, local histories. Therefore large company or industry stakeholders were not recruited and instead local and regional cultural and heritage funding was sought and awarded. Due to the deep project integration across the regions many schools, libraries, museums, and heritage sites, even though project funding has concluded the work is sustained and ongoing.

Geojournalist

This lecture shared takeaways from an ongoing project currently at the prototype level, to teach elementary schoolchildren about the geological heritage of the Plåtbergens Geopark and Bioserve in Sweden. Using a gamification approach, a 2D puzzle interactive narrative game prototype was developed, first as a paper prototype, then as a digital image mockup, and then as a fully interactive digital prototype in Unity game engine. Using a design approach that focused on defining the purpose, audience, aesthetics, and technology for the project, the strategy emerged to create a game structure that was a flexible container and can be easily expanded over time. Testing the prototypes in a variety of contexts resulted in key revisions such as greatly condensing the text in the game, as well as experimenting with museum kiosk-based version that would include physical elements as well as digital elements, for a mixed reality approach. Key insights included the need for good communication between client and developers, and the need for developers to balance sourcing information from the client with independent work. Future steps

for the project may include work with schoolteachers, as the vision for the project is in-classroom use, either before or after school group site visits to the Geopark.

From Art Game Obstruction to Ludokonst

This lecture focused on a series of projects that all share emphasis on creating platforms for interaction, at the intersection of games, art, and performance. Art Game Obstruction was a 2015 participatory art exhibition that was developed in collaboration between a summer school university course and local art museum, with involvement from several visiting artists. The exhibition was open to the public over the course of the whole development period and included interaction modes like DIY hacktivism, modding, and Nordic LARP (live action role play) to invite the public, students, and artists into conversation together around the role of games in society. Future Media Theatres was a network building project that ran from 2020-2021 and facilitated a series of online conversations and in-person performances and salons all on the topic of intersections of games and performing arts. Over 60 people participated from countries all around the world, from across academia and the professional arts sector. A key result from the project was the need for a physical location for interdisciplinary exploration and prototyping, and this need led to the founding of PlayLab research centre in 2022. Since its opening in 2022, PlayLab has hosted residencies, workshops, courses, and festivals such as the Ludokonst biennial in 2023, which presented a series of prototype performance works that utilise game structures and game technologies, for the public to participate in.

Fast Familiar and Adventures in Inclusion

This lecture shared insights from the production and touring of an award-winning interactive theater work, *The Acquisitions Panel*, by Fast Familiar. This theater company creates interactive, audience-centric artworks that tackle questions and problems considered too difficult to approach. The Acquisitions Panel focuses on a real object with a complex colonial past, the decision making process of a local museum advisory board to acquire the object, or not, and if so, how to position it. The object in question is an African thumb piano made from an English biscuit tin that was found in the Congo. Groups of 9-12 participants meet in a room with a physical copy of the real object and use iPads to go through an interactive decision making and discussion process regarding the possible accession of the object. The iPads have video interviews with museum curators and members of the Congolese diaspora, and expose participants to a wide range of informed and sometimes surprising or contradictory viewpoints on the object. In the end of the experience, the group makes their own decision.

Insights from the development of this work and others by Fast Familiar were distilled as a set of 5 principles for inclusive design:

1. Cover the basics (for example, subtitles, fonts, sign-posting information, bathroom locations, experience duration and live progress bar)
2. Descend into the particular (conversations that are too general become abstract and devolve into groupthink and polarisation Be specific and ground

the discussion in something very concrete, give specific discussion prompts and specific tasks)

3. Structure is Everything (think about the smallest possible intervention to open the widest possible access, take approaches that keep the group of participants together and in conversation as opposed to splitting them apart, and give people the tools they need to build knowledge and take risks)
4. Whose voices? (Bring in all the relevant voices to the conversation and work to highlight resilience of oppressed people without minimising atrocities, for example)

Fear is the enemy of change (fear of saying the wrong thing, being embarrassed, being hated or ridiculed, or getting 'cancelled' all leads to silence. Emphasise the value of trying as opposed to perfection).

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Annex 1: Sample of Studies Considered in the Literature Review

Emilo Rossi, Sarah Jane Cipressi

Year	Authors	Title	Source
2024	Del Soldato E.; Massari S.	Creativity and digital strategies to support food cultural heritage in Mediterranean rural areas	EuroMed Journal of Business
2024	Mercuri F.; Pietroni E.; d'Annibale E.; Paoloni S.; Ferdani D.; Zammit U.; Ronchi D.; Fanini B.; Orazi N.	4D thermo-reflectography of cultural heritage. The Codex 4D project: From data acquisition to the implementation in innovative virtual and mixed reality platforms	Journal of Cultural Heritage
2024	Liew C.L.; Passau V.	The Auckland War Memorial Museum Online Cenotaph: community participation, collective memorialisation and social cohesion	Global Knowledge, Memory and Communication
2024	O'Shea S.; Surtees A.	Re-Membering Music Worlds: Exhibiting the Rebel Women of Manchester's Suffragette City	Popular Music and Society
2024	Anastasovitis E.; Georgiou G.; Matinopoulou E.; Nikolopoulos S.; Kompatsiaris I.; Roumeliotis M.	Enhanced Inclusion through Advanced Immersion in Cultural Heritage: A Holistic Framework in Virtual Museology	Electronics (Switzerland)
2024	Cesário V.; Campos P.	The Integrated Museum Engagement Model (IMEM): Bridging Participatory Design, Immersive Storytelling, and Digital Representation for Enhanced Museum Experiences	International Journal of the Inclusive Museum
2024	Giacobone G.A.; Mincolelli G.; Imbesi S.	Inclusive cultural heritage in Europe: co-designing an accessible user experience for digital architectural conservation	Journal of Architectural Conservation

2024	Qsymah A.; Shdaifat I.A.; Ayasarh M.; Qi'dan D.; Al-Housan A.-Q.	HBIM for Sustainable Documentaion of Historic Buildings: Case Study of Al-Faddain Umayyad Mosque	Civil Engineering and Architecture
2024	Li J.; Pan J.; Dou Q.; Fu F.; Shi Y.	Digital Footprint as a Public Participatory Tool: Identifying and Assessing Industrial Heritage Landscape through User-Generated Content on Social Media	Land
2024	Jarrar N.	Developing digital Islamic heritage sites in Jordan: The case of al-Mafraq	Digital Applications in Archaeology and Cultural Heritage
2023	Kantaros A.; Soulis E.; Alysandratou E.	Digitization of Ancient Artefacts and Fabrication of Sustainable 3D-Printed Replicas for Intended Use by Visitors with Disabilities: The Case of Piraeus Archaeological Museum	
2023	Innocente C.; Ulrich L.; Moos S.; Vezzetti E.	A framework study on the use of immersive XR technologies in the cultural heritage domain	Journal of Cultural Heritage
2023	Handzic M.; Pandzic I.	Digital Archaeology in Bosnia and Herzegovina: Current State and Future Challenges	Internet Archaeology
2023	Vrebos H.; Biedermann P.; Moere A.V.; Hermans K.; Hannes K.	The StoryMapper: Piloting a Traveling Placemaking Interface for Inclusion and Emplacement	Social Inclusion
2023	McDonagh S.	Accessing Northern Ireland's contested past: Creating descriptive guides of the Maze and Long Kesh prison video tours	Journal of Specialised Translation
2023	Wessels S.; Maape S.; Schoville B.J.; Wilkins J.	The Drone, the Snake, and the Crystal: Manifesting Potency in 3D Digital Replicas of Living Heritage and Archaeological Places	Archaeologies
2023	Liu Z.; Zhang M.; Osmani M.	Building Information Modelling (BIM) Driven Sustainable Cultural Heritage Tourism	Buildings
2023	Burgo C.	Teaching during COVID-19 Social justice and Spanish heritage language learners	AILA Review
2023	Tuominen I.; Ballardini R.; Mähönen J.; Pihlajarinne T.	Protecting and Accessing Indigenous Peoples' Digital Cultural Heritage through Sustainable Governance and IPR Structures – The Case of Sámi Culture	Arctic Review on Law and Politics

2023	Trovato G.	Postproduction in the Research on the Urban Cultural Landscape: From the Transfer of Results to the Exchange of Knowledge on Digital Platforms and Social Networks – The TRAHERE Project in Madrid	Land
2023	Pagliano A.; Ansaldi B.	Digital Visualization and Multimedia for Cultural Heritage Accessibility: Designing “for All” Video-Tours at the Archaeological National Museum of Naples (Mann)	SCIRES-IT
2023	Pescarin S.; Bonanno V.; Marasco A.	Social Cohesion in Interactive Digital Heritage Experiences	Multimodal Technologies and Interaction
2023	Molho J.	The promises and limitations of digital participation in heritage: Planning transmedia heritage districts in superdiverse cities	International Journal of Heritage Studies
2023	Maietti F.	Heritage Enhancement through Digital Tools for Sustainable Fruition – A Conceptual Framework	Sustainability (Switzerland)
2023	Vargas E.; Villelli M.B.	The digital transition of archaeological heritage: two digitalization experiences in North-patagonia (Río Negro Province and Nahuel Huapi National Park)	Revista del Museo de Antropología
2023	Rouhani B.	Ethically Digital: Contested Cultural Heritage in Digital Context	Studies in Digital Heritage
2023	Nisi V.; Bala P.; Cesário V.; James S.; Del Bue A.; Nunes N.J.	"Connected to the people": Social Inclusion & Cohesion in Action through a Cultural Heritage Digital Tool	Proceedings of the ACM on Human-Computer Interaction
2023	Millán-Millán P.M.; Chacón-Carretón C.; González C.C.	The Process of Digital Fabrication and 3D Printing as a Tool in the Study of Heritage Pathologies: Carcabuey Castle (Cordoba)	Virtual Archaeology Review
2023	Grammatikopoulou A.; Grammalidis N.	Artful – An AR Social Self-Guided Tour App for Cultural Learning in Museum Settings	Information (Switzerland)
2023	El-Husseiny M.-A.; El-Dessouki A.; El-Husseiny A.	Exploring Inclusivity of Storytelling Museums in Cairo through Developing an Educational Adventure	New Design Ideas

2023	Pistofidis P.; Arnaoutoglou F.; Ioannakis G.; Michailidou N.; Karta M.; Kiourt C.; Pavlidis G.; Mouroutsos S.G.; Tsiadaki D.; Koutsoudis A.	Design and evaluation of smart-exhibit systems that enrich cultural heritage experiences for the visually impaired	Journal of Cultural Heritage
2022	Giuffrida D.; Mollica Nardo V.; Neri D.; Cucinotta G.; Irene Calabrò V.; Pace L.; Ponterio R.C.	Digitization of two urban archaeological areas in Reggio Calabria (Italy): Roman Thermae and Greek fortifications	Journal of Archaeological Science: Reports
2022	Baratin L.; Gasparetto F.; Tronconi V.	Raising awareness on conservation: developing best practices for a “participatory care” of the murals in the city of Pesaro	DISEGNARECON
2022	Sung H.-Y.; Tsai T.-I.	Policy Development for Public Libraries in Taiwan: From the Perspectives of Library Practitioners and Experts	Journal of Library and Information Studies
2022	Shiri A.; Howard D.; Farnel S.	Indigenous Digital Storytelling: Digital Interfaces Supporting Cultural Heritage Preservation and Access	International Information and Library Review
2022	Giuffrida D.; Bonanno S.; Parrotta F.; Nardo V.M.; Anastasio G.; Saladino M.L.; Armetta F.; Ponterio R.C.	The Church of S. Maria Delle Palate in Tusa (Messina, Italy): Digitization and Diagnostics for a New Model of Enjoyment	Remote Sensing
2022	Hijazi A.N.; Baharin H.	The Effectiveness of Digital Technologies Used for the Visitor’s Experience in Digital Museums. A Systematic Literature Review from the Last Two Decades	International Journal of Interactive Mobile Technologies
2022	de Fino M.; Bruno S.; Fatiguso F.	Dissemination, Assessment and Management of Historic Buildings by Thematic Virtual Tours and 3D Models	Virtual Archaeology Review
2022	Canazza S.; De Poli G.; Vidolin A.	Gesture, Music and Computer: The Centro di Sonologia Computazionale at Padova University, a 50-Year History	Sensors
2022	Hackney F.; Onions L.; Rogers G.; Figueiredo D.; Loveday M.	Maker-centricity and ‘edge-places of creativity’: CARE-full making in a CARE-less world	European Journal of Cultural Studies
2022	Malezanov I.; Kavur M.B.	Virtual accessibility of the Macedonian tomb in Ohrid	Studia Universitatis Hereditati
2022	Middle S.; Horne R.; McMeekin D.A.; Zuanni C.; Butterworth A.	Geographies of Place in Digital Art History	International Journal of Humanities and Arts Computing

2022	Daga E.; Asprino L.; Damiano R.; Daquino M.; Agudo B.D.; Gangemi A.; Kuflik T.; Lieto A.; Maguire M.; Marras A.M.; Pandiani D.M.; Mulholland P.; Peroni S.; Pescarin S.; Wecker A.	Integrating Citizen Experiences in Cultural Heritage Archives: Requirements, State of the Art, and Challenges	Journal on Computing and Cultural Heritage
2022	Ibrahim A.	The role of museums, design accessibility and community concerns: A case study of the State Bank of Pakistan Museum & Art Gallery	Journal of Community Archaeology and Heritage
2022	Chivăran C.; Capece S.	Multidirectional and Multilevel Models of Museum Enjoyment and Use between Spatial Narration and Multisensory Perceptual Experience	Boletín de Arte
2022	Kuan T.H.; Shiratuddin N.	Components of Adaptive Augmented Reality Model for Heritage Mobile Application	International Journal of Interactive Mobile Technologies
2022	Mileusnić Z.; Bugar A.	Museum accessibility: development of good practice for the promotion of archaeological heritage	Studia Universitatis Hereditati
2021	Alakija O.B.	Living with difference: Ontological security and identification of second-generation members of the Nigerian diaspora in Peckham, 'Little Lagos', London	Journal of Arab and Muslim Media Research
2021	Giuffrida D.; Nardo V.M.; Neri D.; Cucinotta G.; Calabrò I.V.; Pace L.; Ponterio R.C.	A multi-analytical study for the enhancement and accessibility of archaeological heritage: The churches of san nicola and san basilio in Motta Sant'Agata (RC, Italy)	Remote Sensing
2021	Snis U.L.; Olsson A.K.; Bernhard I.	Becoming a smart old town – How to manage stakeholder collaboration and cultural heritage	Journal of Cultural Heritage Management and Sustainable Development
2021	Gómez-ruiz M.-L.; Morales-yago F.-J.; de Lázaro-Torres M.-L.	Outdoor education, the enhancement and sustainability of cultural heritage: Medieval madrid	Sustainability (Switzerland)
2021	Duester E.	How Digitization is Empowering Vietnamese Cultural Professionals to Preserve, Present, and Promote Art and Culture Online: Navigating Challenges whilst Harnessing Opportunities to Create a Digital Culture	Preservation, Digital Technology and Culture

2021	Turilazzi B.; Leoni G.; Gaspari J.; Masari M.; Boulanger S.O.M.	Cultural Heritage and Digital Tools: The Rock Interoperable Platform	International Journal of Environmental Impacts
2021	Maietti F.; Di Giulio R.; Medici M.; Ferrari F.; Piaia E.; Brunoro S.	Accessing and Understanding Heritage Buildings through ICT. The INCEPTION Methodology Applied to the Istituto degli Innocenti	International Journal of Architectural Heritage
2021	Bagnolo V.; Argiolas R.; Bellumori F.C.	Digital Gypsotheque. Online Features as Inclusive Educational Tool	SCIRES-IT
2021	Zohar M.; Shimshoni I.	GIScience integrated with computer vision for the examination of old engravings and drawings	International Journal of Geographical Information Science
2021	Rasoloniaina F.L.	Phantasmagoria	International Journal of the Inclusive Museum
2021	Gandhi P.; Ravi C.; Pathak P.; Jaliha S.	Museums and Heritage Sites – The Missing Link in Smart City Planning: A Case Study of Pune City, India	Space and Culture, India
2021	García-León J.; González-García J.A.; Collado-Espejo P.E.	Documentation and Modelling of a Hypothetical Reconstruction of the First Roman Watermill in Hispania	Virtual Archaeology Review
2021	Giacconi C.; Ascenzi A.; Del Bianco N.; D'Angelo I.; Capellini S.A.	Virtual and augmented reality for the cultural accessibility of people with autism spectrum disorders: A pilot study	International Journal of the Inclusive Museum
2021	Chivăran C.	Knowing the invisible dimensions of water through augmented interactions and perceptions; [Cunoașterea dimensiunii invizibile a apei prin interacțiuni și percepții aumentate]	Sustainable Mediterranean Construction
2021	Pietroni E.; Pagano A.; Biocca L.; Frassinetti G.	Accessibility, natural user interfaces and interactions in museums: The intarsi project	Heritage
2021	Mutaz T.; Khalid Z.; Kamoona H.H.A.	The revival of the historic Islamic geometric pattern on the gate of The Al-Sharabeya School in Wasit City using the Grasshopper program	Periodicals of Engineering and Natural Sciences
2021	Viñals M.J.; Gilabert-Sansalvador L.; Sanasaryan A.; Teruel-Serrano M.-D.; Darés M.	Online synchronous model of interpretive sustainable guiding in heritage sites: The avatar tourist visit	Sustainability (Switzerland)
2020	Quiñones Vilá C.S.	What's in a name? Museums in the post-digital age	Santander Art and Culture Law Review

2020	Kosmas P.; Galanakis G.; Constantinou V.; Drossis G.; Christofi M.; Klironomos I.; Zaphiris P.; Antona M.; Stephanidis C.	Enhancing accessibility in cultural heritage environments: considerations for social computing	Universal Access in the Information Society
2019	Gill H.; Vos J.; Villa-Torres L.; Ramirez M.S.	Migration and Inclusive Transnational Heritage: Digital Innovation and the New Roots Latino Oral History Initiative	Oral History Review
2019	Fraisse A.; Zhang Z.; Zhai A.; Jenn R.; Fishkin S.F.; Zweigenbaum P.; Favier L.; El Hadi W.M.	A sustainable and open access knowledge organization model to preserve cultural heritage and language diversity	Information (Switzerland)
2019	Politopoulos A.; Ariese C.; Boom K.; Mol A.	Romans and rollercoasters: Scholarship in the digital playground	Journal of Computer Applications in Archaeology
2019	Marasco A.; Balbi B.	Designing accessible experiences for heritage visitors through virtual reality	e-Review of Tourism Research
2019	Cerdan Chiscano M.; Binkhorst E.	Heritage sites experience design with special needs customers	International Journal of Contemporary Hospitality Management
2018	Villalobos N.F.; Cazorla M.P.	Perception and wayfinding at cultural sites	International Journal of Visual Design
2017	Bruttini E.; Di Corato L.; Lusini V.	Living Heritage: Digital Ecomuseums in the Terre di Siena	Museum International
2017	Balzani M.; Maietti F.	Architectural space in a protocol for an integrated 3d survey aimed at the documentation, representation and conservation of cultural heritage	Disegno
2017	Pohawpatchoko C.; Colwell C.; Powell J.; Lassos J.	Developing a Native Digital Voice: Technology and Inclusivity in Museums	Museum Anthropology
2016	Liew C.L.	Social metadata and public-contributed contents in memory institutions: "crowd voice" versus "authenticated heritage"?	Preservation, Digital Technology and Culture
2016	Balela M.S.; Mundy D.	Exploring Approaches to the Generation and Representation of Heritage Artefacts in Video Game Contexts	Asia Pacific Media Educator
2015	Thompson S.	The Jazeera Al Hamra Digital Heritage Project: A Model for Digitally Preserving the	International Journal of the Inclusive Museum

		Heritage of the Arabian Peninsula	
2015	Ibrahim N.; Ali N.M.; Yatim N.F.M.	Factors facilitating cultural learning in virtual architectural heritage environments: End user perspective	Journal on Computing and Cultural Heritage
2014	Pietroni E.; Adami A.	Interacting with virtual reconstructions in museums: The etruscanning project	Journal on Computing and Cultural Heritage
2013	Minucciani V.; Garnero G.	Geomatics and virtual tourism	Journal of Agricultural Engineering
2013	Battle M.	Re-envisioning the Museum: Developing the International African American Museum in Charleston, South Carolina during an economic crisis	International Journal of the Inclusive Museum
2013	Lupo E.; Özdil E.	Towards a "smart heritage" As future diffused museums: Design and communication technologies to innovate the experience of the cultural patrimony in smart cities	International Journal of the Inclusive Museum
2012	Giersing S.	Moving the walls: Participatory strategies of the Museum of Copenhagen	International Journal of the Inclusive Museum
2012	Robles-Ortega M.D.; Feito F.R.; Jiménez J.J.; Segura R.J.	Web technologies applied to virtual heritage: An example of an Iberian Art Museum	Journal of Cultural Heritage
2010	Foni A.E.; Papagiannakis G.; Magnenat-Thalmann N.	A taxonomy of visualization strategies for cultural heritage applications	Journal on Computing and Cultural Heritage
2010	Schettino P.; Kenderdine S.	Place-Hampi: Narratives of inclusive cultural experience	International Journal of the Inclusive Museum
2009	Topoleanu F.; Popescu O.; Tache A.; Petrișor A.-I.; Bica I.; Bajenaru O.	Management of archaeological sites in Tulcea County using an integrated geospatial system for their positioning and protection	Annales d'Universite 'Valahia' Targoviste, Section d'Archeologie et d'Histoire
2008	Jochems R.	Your base, my base: Good practices on diversity in the Heritage sector	International Journal of the Inclusive Museum
2008	Ciolfi L.; Bannon L.; Fernstrom M.	Including visitor contributions in cultural heritage installations: Designing for participation	Museum Management and Curatorship

Annex 2: Database of Case Studies

**Francesca Caramanico, Erika Ferrara, Cristina Iacobucci, Cecilia Molon,
Ester Tagliafierro**

<https://airtable.com/appnROy5YfOJ3EAxk/shreG5SoKQgcFYrJj>

Annex 3: Inclusive Design and 3D Technologies

Beatriz Rayón Viña, Duna Martínez del Barrio

Innovation is any change (not only technological)
based on knowledge (not only scientific)
that generates value (not only economic).
- Definition of *Innovation*. COTEC Foundation

The starting point of this section could be an adaptation of the definition of innovation given by COTEC Foundation, which reads as follows:

Inclusivity is any change (not only procedural) based on understanding (not only theoretical) that generates value (not only economic).

This inclusiveness is more than formal procedures and policies; it encompasses cultural changes, attitudes and daily practices that promote an inclusive environment. In essence, inclusiveness is based on a comprehensive understanding of diverse perspectives, experiences and needs, rather than mere theoretical concepts: it requires active engagement and learning from diverse communities. Thus, the MediaLab team has therefore decided to initiate its reflection by asking themselves the following questions: how, what and for whom do we want to make inclusive designs? How are we going to achieve inclusivity?

This inclusiveness is more than formal procedures and policies; it encompasses cultural changes, attitudes and daily practices that promote an inclusive environment. In essence, inclusiveness is based on a comprehensive understanding of diverse perspectives, experiences and needs, rather than mere theoretical concepts: it requires active engagement and learning from diverse communities. Thus, the MediaLab team has therefore decided to initiate its reflection by asking themselves the following questions: how, what and for whom do we want to make inclusive designs? How are we going to achieve inclusivity?

First, the value generated by inclusivity¹¹ transcends financial considerations and encompasses social, cultural and emotional benefits, such as strengthening communities, improving well-being and increasing collaboration. This means that more and more people can effectively develop their own project of a *good life*¹²,

¹¹ Cambridge Dictionary def: 'the fact of including all types of people, things or ideas and treating them all fairly and equally'.

¹² The Aristotelian concept of the 'good life' (or *eudaimonia*) refers to a life of flourishing and fulfillment, achieved through the practice of virtue and the use of reason in accordance with one's

while at the same time helping to rethink how some people's project of a *good life* can hinder or undermine those of others. In the field of design, combining inclusive principles with 3D printing technology offers a strong tool to close gaps between people with different abilities. 3D-printed models offer significant advantages for accessibility, especially for those with print disabilities and haptic learners. These models are not only 'understood through both vision and touch' but are also 'cheaper or easier to obtain than other options such as commercial products or real objects' (Holloway, 2024, p. 10). Their physical nature allows users to explore objects that are otherwise inaccessible, including those 'too small, too large, too dangerous, too precious, too rare or not available to be touched' (Holloway, 2024, p. 10). This tactile engagement is particularly useful for haptic learning style, which emphasizes interaction through touch and manipulation. Haptic learning involves a kinesthetic and tactile approach, where users grasp concepts better by physically interacting with materials. 3D models are an excellent tool for this style of approach, as they allow for hands-on exploration, helping learners internalize abstract or theoretical content. These models can be 'optimized for touch reading and inclusion' by simplifying unnecessary details and providing clear tactile distinctions, essential for haptic learners and those with visual impairments (Holloway, 2024, p. 10). Braille labels and various tactile features also enhance learning for individuals with different abilities by engaging their sense of touch. For example, models designed for touch can be enhanced with 'contrasting colors to highlight important features', which benefits learners with low vision as well (Holloway, 2024, p. 45).

This connection between 3D models and the haptic learning style is particularly effective in educational fields such as science, geography, and art; which is very convenient to bring the natural and cultural heritage closer and make it accessible. Haptic learners, for instance, could better understand topography by handling 3D-printed models of landscapes rather than merely viewing flat, 2D maps. By incorporating these elements into education, we make learning more inclusive and aligned with the needs of diverse people, including those who rely heavily on their sense of touch to process information. Simultaneously, these sources could help to protect and honor both our cultural and natural heritage. Understanding abilities across different cultures reveals a wide range of perspectives: this because what is considered a valuable skill or capability can differ greatly from one society to another. For instance, artistic talent, survival techniques, or social skills and manners are seen through distinct cultural viewpoints, shaped by each society's history and norms. This diversity encourages us to adopt a broader understanding of what ability means, which transcends strict definitions and helps us determine what kind of design we want to do.

Understanding Disabilities and Social Perspectives

On the one hand, physical disabilities generally refer to conditions that impact a person's physical functioning or capacity to perform tasks and activities. These can

true nature. For a deeper and broader concept see: <https://plato.stanford.edu/entries/ethics-virtue/#EudaVirtEthi>

arise for various reasons, such as genetics, injury, or illness, and are often defined by how society views differences in physical function. Disabilities can significantly affect a person's life, influencing areas such as vision, movement, cognitive functions, memory, learning, communication, hearing, mental health, and social interactions. Disabilities have different degrees, as for example blindness refers to a complete loss of sight, whilst low vision means a person has limited sight. Hearing loss or impairment makes it harder to hear, and locomotor disabilities limit the movement of certain body parts. Learning disabilities can make reasoning, thought-processing, and problem-solving more difficult, while mental health conditions affect how a person thinks, feels, behaves, and experiences emotions.

However, the social model of disability focuses on how society responds to these differences, rather than the differences themselves, arguing that it is the environment that creates barriers, not the individual condition. These social, economic, architectural, and epistemic barriers¹³ render invisible and exclude, thereby disabling any possibility of thinking about true inclusive policies and initiatives. In contrast to traditional views that often label disability as a weakness, the concept of *disability culture* presents a different and valuable perspective. This concept views disability as a key part of *identity, community, and individual contributions to society*. This approach emphasizes the importance of inclusive practices that support and celebrate different abilities, challenging stereotypes and promoting respect and equality. In order to achieve real inclusiveness we must, therefore, take into account the needs of the disabled person, and not only the adaptation of their condition to the 'able-bodied' standard. In order to carry out a respectful inclusive design, it is important to take into account that the inclusion of the other starts from the design and from the disabled person's own perspective on what they want and need. This means that their presence and voice are essential at every stage of the design process, from planning to execution, ensuring that their identity and needs are heard and reflected. Co-creating with people with disabilities not only results in more accessible products and services, but also empowers these individuals by recognizing their experiences and skills.

Handling Cultural and Natural Heritage Through 3D Technologies

By combining inclusive principles with the capabilities of 3D printing, we can empower individuals whilst promoting respect, equality, and an appreciation for diverse abilities across different cultures and societies. 3D printing offers various ways to incorporate touch and other non-visual senses into cultural experiences,

¹³ An epistemic barrier refers to obstacles that hinder the acquisition, dissemination, or understanding of knowledge and information. These barriers can arise from various factors, such as cognitive biases, cultural differences, social norms, or institutional practices that limit access to information or the ability to engage with it effectively. Epistemic barriers can prevent individuals or groups from fully comprehending complex ideas, participating in knowledge production, or contributing to discussions, ultimately impacting learning and communication processes.

making cultural heritage more accessible to people with learning disabilities, children, the elderly, or those who are blind or visually impaired¹⁴. This approach allows for a more complete understanding of cultural heritage, introducing a new way of 'seeing' culture by integrating multisensory elements (Echavarria & Samaroudi, 2019; Hewitt, 2015). For example, creating 3D representations of sculptures enables individuals to experience vision through touch, bringing cultural subjects closer in ways previously unavailable. However, the question arises of how we can apply this technology to natural heritage or large-scale cultural sites. The application of 3D technologies is not limited to individual artifacts but extends to broader areas of cultural preservation, including both tangible and intangible cultural heritage (TCH and ICH) (Skublewska-Paszkowska et al., 2022). 3D technologies aid in the documentation, protection, and dissemination of cultural heritage, as we can for example see on the *Virtual Ganjali Khan Project* (Bozorgi & Lischer-Katz, 2020). This project focuses on the application of 3D scanning and immersive virtual reality (VR) technologies to digitally preserve the Ganjali Khan Complex, a historic site in Kerman, Iran. The project aims to 'digitally preserve, expand access to, and develop new scholarly tools for studying the Ganjali Khan Complex' by creating 'high-fidelity 3D models that will be used to build immersive virtual reality (VR) experiences of the Complex' (Bozorgi & Lischer-Katz, 2020, p. 45). Through these technologies, they say, researchers can analyze the complex at a human scale in a virtual environment, enabling the discovery of new details, such as 'patterns or textures in the tile work and ornamentation that are not visible in flat 2D images' (Bozorgi & Lischer-Katz, 2020, p. 47). These immersive tools also allow users to virtually 'walk through' the site, providing an experience that is both proportionally accurate and interactive (Bozorgi & Lischer-Katz, 2020, p. 50). The potential of 3D/VR tools in expanding research and cultural heritage work is vast, as these technologies hold significant promise for impacting fields such as history, architecture, and urban planning, offering new ways to engage with and preserve cultural heritage (Bozorgi & Lischer-Katz, 2020). Therefore, these technologies not only make heritage elements more accessible – 'allow[ing] access to the cultural heritage elements that are difficult to reach in the real world' (Skublewska-Paszkowska et al., 2022, p. 2) – but also offer new insights into cultural studies through the combination of audiovisual and 3D techniques. This results in a deeper understanding of heritage across diverse audiences. The authors emphasize that 3D technologies have become a key tool in preserving cultural heritage for future generations, stating that 'the preservation of cultural heritage has become an anchor of the past towards future generations due to 3D technologies' (Skublewska-Paszkowska et al., 2022, p. 20). In the same way these studies and projects highlight the preservation and transmission of cultural heritage for future generations, we propose that this process should also incorporate principles of inclusivity, ensuring equal access for all individuals, regardless of their abilities. This approach broadens the perspective on both what and how these technologies are developed.

Regarding natural heritage, 3D printing and VR may be suitable methods to make remote places, sacred sites and fragile environments accessible without causing harm to any of the parties involved, thereby respecting the heritage and also making

¹⁴ For example, see the work of the organization See3D - 3D Printing for the Blind at <http://see3d.org/>

it accessible. This accessibility we are talking about must be inclusive from the initial conception or idea, involving possible and potential users who will want to enjoy these resources. Consider, for example, remote communities located deep within natural reserves, where ancient geological formations or rare plant and animal species are hidden from the wider public. These areas are often kept out of reach not only because of logistical difficulties, but also out of respect for nature and the need to preserve and protect it. With 3D printing, these natural wonders could be carefully recreated as detailed tactile models that accurately reflect their intricate details (Skublewska-Paszkowska et al., 2022). For instance, designers and scientists could work with a national park known for its unique rock formations to create precise 3D-printed replicas or VR 'spaces'. These models could be displayed in visitor centers, educational places or other public places, providing tactile and immersive experiences that help people to better understand and appreciate the park's natural beauty, making this heritage accessible not only to people with disabilities, but to all those outside this environment, respecting and preserving it at the same time. Additionally, these forms of 'virtual tourism' and 'virtual accessibility' play a crucial role in conservation by reducing the physical deterioration that many historical sites face due to mass tourism, which often leads to damage and degradation. By providing virtual access, it not only helps preserve these sites for future generations but also ensures that everyone, regardless of physical ability or geographic location, can experience their beauty and cultural significance. A place that is inaccessible – whether physically or metaphorically – excludes individuals from being a part of its story. True inclusivity in cultural and natural heritage requires more than passive acceptance; it demands proactive laws, frameworks, and initiatives that promote active participation for all. Inclusivity should not be about merely 'tolerating' those who are included, but about celebrating and embracing diversity in all its forms.

Our epistemic knowledge and societal responsibility

Understanding how we acquire knowledge – epistemic knowledge – is essential in this study. It is not only about what we know, but also about how the methods we use shape our knowledge and define its limits. This exploration goes beyond mere facts, requiring us to critically examine how knowledge is collected, validated, and used in different contexts. Our epistemic knowledge can be modeled to broaden our understanding and bring together diverse capabilities in a way that unites cultural and natural heritage inclusively. This concept becomes especially important in collaborative innovation processes, where the use of shared epistemic objects plays a crucial role in guiding collective exploration. As outlined by Riikonen et al. (2018), these objects – whether physical artifacts or digital models – serve as central tools in co-invention projects, where participants work together to develop new products, solutions, or innovations. Epistemic objects are not static; they represent evolving knowledge. Participants interact with them, modify them, and refine them as the project progresses. For instance, a 3D model functions as epistemic objects, allowing team members to see the concept they are working on, discuss its details, and make necessary changes. These interactions become a focal point for

collaboration, driving idea generation. As Riikonen et al. note, ‘The number of individual design ideas that formed the final invention was astonishing and signifies further the large quantity of epistemic efforts required to create the invention’ (Riikonen et al., 2018, p. 8). This reflects the immense cognitive and creative effort involved in collaborative processes, where ideas are constantly shaped and reshaped by the group's contributions. In co-invention projects, shared artifacts are not just tools; they mediate the creative process, facilitating communication and aligning participants’ understanding of the project. For example, in the design of a building, a shared digital model can help architects, engineers, and other stakeholders visualize their collective goals, explore different design options, and make informed decisions. By embodying the goals and knowledge of the project, the artifact helps participants engage in deeper conversations and contribute more effectively. These shared epistemic objects also encourage creativity by providing tangible representations of ideas, which can often be difficult to express verbally. Manipulating or refining the artifact allows participants to experiment, test ideas, and see how different components fit together, leading to new ways of thinking that may not have emerged otherwise. As Riikonen et al. point out, ‘Being able to form a model of the epistemic object helps us to consider what kind of learning takes place during co-invention processes’ (Riikonen et al., 2018, p. 8). This dynamic interaction fosters learning and development, as the object evolves in response to ongoing contributions from the team. From an epistemological standpoint, this approach allows us to see how our knowledge influences our perspectives on abilities, disabilities, and cultural heritage. By incorporating different ways of knowing and thinking into our design processes, we gain a deeper understanding of the world and ensure that our technological advancements uphold ethical standards and promote inclusivity across various cultures. In the broader context of co-invention projects, the use of shared epistemic objects underscores the complex interplay between knowledge, creativity, and collaboration. These objects act as externalized representations of the ideas driving the project forward, offering a space for participants to engage, experiment, and co-create. To achieve this efficiently, discourses and environments must implement representations, values, and practices that gradually deconstruct the very concept of ability, whether we understand ability as physical, material, or symbolic. This is why it is so important to understand and reconfigure the design of environments and the construction of *imaginaries*. As Toboso points out, “abilities, as socially valued and privileged qualities, are as conditioned by our organic constitution as by the characteristics of the sociocultural context we inhabit, which provides the aforementioned valuation” (Toboso Martín, 2021, p. 5)¹⁵.

However, in order to achieve inclusiveness under the first given definition¹⁶, it is also needed to review the concept of what disability and ability means. To this end, it is of utmost importance to recognize how the concept of disability has been scientifically conceptualized. Historically, we can refer to Kuhn's notion of a paradigm, which is understood as a set of universally recognized scientific

¹⁵ Translated from the Spanish: ‘las capacidades, en tanto cualidades socialmente valoradas y privilegiadas, están tan condicionadas por nuestra constitución orgánica como por las características del contexto sociocultural que habitamos, el cual aporta la mencionada valoración’.

¹⁶ I.e.: Inclusivity is any change (not only procedural) based on understanding (not only theoretical) that generates value (not only economic).

achievements during a certain period, providing models of problems and solutions. In our case, we are particularly interested in the paradigm of personal autonomy (the social model and the functional diversity model), in 'which the central nucleus of the analysis is no longer in the individual person with a health impairment, but in the social, in the environment which is the one that causes the disability, generating or consolidating exclusion'¹⁷ (Velázquez, 2009, p. 90). Specifically, the social model examines the issue through the lens of integrating individuals with disabilities into society, asserting that disability is not a characteristic of the person but rather emerges from a complex interplay of conditions, many of which are influenced or worsened by the surrounding social environment. In this sense, 3D designs and projects focused on inclusivity contribute significantly to a paradigm shift in the conception of disability. The aim is not normalization but understanding disability as a social issue, stemming from the very social environment that disables certain groups. Understanding this, we will realize that the body is completely regulated by forms of functioning and by the compulsory incorporation of those normative abilities into the body. As a society, we have a significant responsibility to ensure that everyone can access our shared natural and cultural heritage, without exception. This responsibility is based on principles of fairness, inclusiveness, and the need to preserve what we have inherited for future generations, all subjects included. By improving access to our cultural treasures and natural wonders, we enhance understanding, foster appreciation for different cultures, and encourage everyone to protect the planet's biodiversity and cultural richness, as the goal is to implement emancipatory practices and frameworks that enable the independence and rehabilitation not so much of individuals themselves, but of society as a whole. If society is rehabilitated, it will lead, in parallel, to the rehabilitation and development of the artifacts, technologies, and spaces created by that society. In other words, it is about understanding and classifying environments as dysfunctional and non-inclusive, rather than categorizing people as dysfunctional. Therefore, the focus should be on intervening in those exclusive and restrictive environments and making them accessible for all.

For example, imagine a project where a community with a rich cultural background collaborates with designers to create detailed 3D-printed replicas of traditional crafts. These replicas are not just souvenirs; they serve as educational tools in local schools and exhibits in museums that everyone can engage with. This illustrates how technology can help preserve and celebrate cultural diversity while making experiences accessible to all. To achieve this, it is essential to involve community members, historians, and accessibility experts in the design process. This ensures that the replicas accurately reflect the true spirit and history of the artifacts, while honoring different cultures and perspectives. By integrating inclusive design with 3D printing, we are making a strong commitment to accessibility and cultural preservation. This partnership empowers individuals and communities, enriching our shared human experience and guiding us toward a future where everyone is included and treated fairly. To move towards that future, the imaginary that

¹⁷ Translated from the Spanish: 'el núcleo central del análisis ya no está en la persona individual con una deficiencia de salud, sino en lo social, en el entorno que es el que discapacita, generando o consolidando la exclusión'.

constructs the models of quality of life must undergo a transformation, as these models are shaped by the individual's ability to do what they desire.

Ethical Design and Epistemic Knowledge

Technology, driven by human creativity, arises from the vision of 'envisioning alternatives to the status quo' (Friedman & Hendry, 2019, p. 1) and reshaping the world to affect both human and nonhuman life. In this context, ignoring values in the design process is no longer acceptable. Technology must be created by 'bringing our moral and technical imaginations' (Friedman & Hendry, 2019, p. 2) into play, ensuring it contributes positively to society by 'envisioning, designing, and implementing technology in moral and ethical ways' (Friedman & Hendry, 2019, p. 2) that benefit everyone. As stated, In the field of natural and cultural heritage, 3D technologies could play a significant role in preserving and promoting protected and remote locations and also traditional practices and artifacts. Communities with rich cultural histories can use this technology to revive endangered crafts or recreate fragile artifacts that cannot be handled. For example, a community known for its detailed pottery techniques could collaborate with designers to produce precise 3D-printed replicas of ancient pottery pieces discovered in archaeological excavations. These replicas could help preserve cultural heritage and act as educational tools in museums or cultural centers, allowing visitors to engage with history in a more interactive way. But not only that, this enriches the ability to look back, to return to technique through technology – to understand it, preserve it, and admire it. To achieve this, the set of available functionalities in all social environments must be expanded to effectively promote equal opportunities. Culture, in this sense, should be understood as the 'set of all functionalities that, in the various social participation environments, constitute the community's possibilities for functioning' (Toboso, 2021, p.17)¹⁸.

For tasks such as the ones we are talking about, applying Value Sensitive Design (VSD) principles ensures that our projects respect ethical standards and cultural sensitivities. These practices focus on inclusivity and authenticity by involving not only final users but all stakeholders, defined as 'direct stakeholders, those who interact directly with the technology; and (2) indirect stakeholders, those who do not directly interact with the technology but may nonetheless be affected' (Friedman & Hendry, 2019, p. 65). In this way, 3D technologies become more than just a tool: they become a transformative mechanism to improve accessibility, inclusion and conservation of natural and cultural heritage around the world and following the principles of the VSD anchors us in the potential involvement of all people who will enjoy -directly or indirectly - what is designed. 3D technologies could emerge as a transgressive tool that redefines how we interact with the environment, culture, and art, whilst preserving our collective identity and human values. In a digitalized and globalized world where collective identity often becomes blurred, the ability to recreate and promote artifacts and traditions is essential for the preservation and

¹⁸ Translated from the Spanish: 'Conjunto de todos los funcionamientos que en los variados entornos sociales de participación, constituyen las posibilidades de funcionamiento de la comunidad'.

strengthening of ancestral places, devices, and knowledge, and making it all accessible to everyone without discrimination represents true inclusion.

This type of design increases the democratization of culture and enhances the interdependence of our stories, forging a cultural narrative that rejuvenates our deteriorating collective identity. These designs establish ‘magical bridges’ between the past and the present that help preserve not only physical objects, but also collective memory, belonging and identity. These ‘bridges’ affect a great diversity of people: for example, people currently excluded due to motor, culture, age, etc., and those who are excluded because of their mobility, culture, age, etc. Value Sensitive Design ensures that technological advancements align with important human values. From the initial concept to the final product, factors like accessibility, cultural relevance, and sustainability shape the development of technologies that honor and reflect diverse cultural viewpoints. This approach goes beyond functionality, focusing on ethical responsibility to create inclusive and socially responsible solutions.

VSD seeks to balance human values with technological innovation, fostering a proactive approach that enhances both the moral and technical dimensions of our evolving world. According to the authors, ‘tightly coupled interaction between our experience of ourselves as human beings and our tools and technologies’ (Friedman & Hendry, 2019, p. 3). A key question in technological evolution is how to design tools that prioritize human flourishing. Value Sensitive Design emerges as a framework that addresses ‘what is important to people in their lives, with a focus on ethics and morality’. VSD integrates technology with ethical considerations, emphasizing the importance of human values in the design process through a ‘tripartite methodology’ (Friedman & Hendry, 2019, pp. 19-onward) of conceptual, empirical, and technical investigations. This approach co-evolves with social structures and technology to create solutions for complex issues. Designers are encouraged to adopt an interactional stance that balances human values and recognizes the complex interactions between technology and society. By engaging with direct and indirect stakeholders, designers ensure that those affected by technology have their values and needs represented. Furthermore, VSD addresses ‘value tensions’ (Friedman & Hendry, 2019, pp. 44-48) in design, seeking to balance and resolve conflicts among values rather than optimizing one at the expense of another. This approach is critical for navigating design trade-offs and ensuring ethical considerations remain central to technological development. VSD advocates progress, not perfection, encouraging incremental improvements in systems that address human welfare and justice while continually refining work to better meet societal needs.

Methods in VSD provide guidance on how to conduct research or design inquiry. ‘Direct and indirect stakeholder analysis’ and ‘Value Source Analysis’ are key tools that ensure human values are integrated into the design process. These methods, detailed by Friedman and Hendry, emphasize the importance of identifying stakeholders and understanding the values that shape both the design and the technology itself. Their methods are broad, applicable to any technology, and emphasize the inclusion of human values in the design of assistive technologies, taking care of functional diversity. Tactile models, for example, could offer visually

impaired individuals a chance to engage with cultural treasures that would otherwise be out of reach.

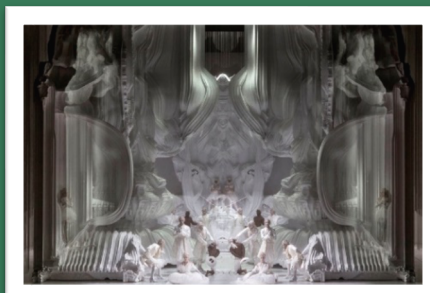
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Annex 4: Complete Dossier of Best Case Studies of Best Practices

Silvia Maria González Fernández

Case study 1

Promotor	Factum Arte	
Project	Michael Hansmeyer's opera for The Magic Flute	
Objective	To recreate the Magic flute scene and ephemeral representation	
Equipment	We use stereolithography 3D printing (also known as SLA or “resin printing”)	
Beneficiary	Factum Arte. Presented at the Théâtre Royal de La Monnaie de Munt in Brussels	
Source	<u>Factum Arte :: Escenografía de La flauta mágica, ópera dirigida por Romeo Castellucci (factum-arte.com)</u>	

Fused filament manufacturing (FFF) is the most common and usually the most accessible process, due to its low material costs and comparatively rudimentary machines. Within Factum, the process is used to produce lower-resolution mock-ups, mold shapes, and mechanical parts such as component housings. In-house machines with build volumes of up to 500 mm³ can be used to manufacture 3D models in a single part or to produce multiple parts that are then joined together to create a larger final shape.


Due to their susceptibility to UV light degradation, SLA 3D prints, unless used as a reference, rematerialize. Objects that need to be cast in metal can be molded in silicone and recreated in wax, or melted directly through a centrifugal casting and burning process.

Selective laser sintering (SLS) uses a laser to sinter, which means heat-solidifying fine particles of powdered material in the areas defined by the 3D model, building the shape layer by layer and leaving the finished object suspended in the surrounding unsintered powder. SLS is an ideal process for end-use parts, such as the busts created by the Veronica 3D scanner, where the surface texture of the powder effectively represents that of human skin. SLS parts are generally more

stable and resistant to UV light and are therefore often used as mechanical components in both prototyping and end-use applications. The opera of *The Magic Flute / Die Zauberflöte* by Romeo Castellucci, presented at the Théâtre Royal de La Monnaie de Munt in Brussels. *The Magic Flute* is one of Mozart's most famous works and one of the most beloved in the entire operatic repertoire. Director Romeo Castellucci has deliberately moved away from the narrative dimension of opera to explore its raw emotion and philosophical heart.

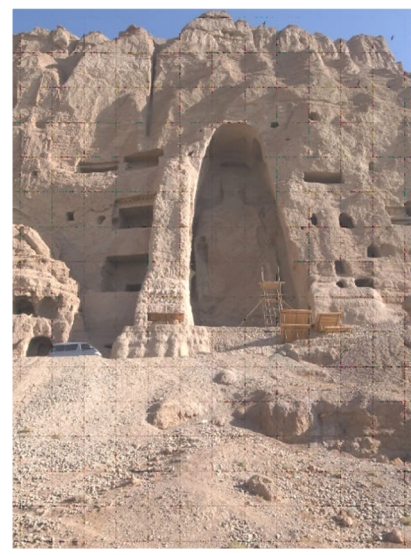
Before being milled, Factum's design team created a 3D model to predict the outcome. It is composed of nine elements in total: four pieces were suspended five or six meters above the ground, while the other five are mobile along the base of the structure. Due to its size, it was crucial to divide each of these nine elements so that the opera house could be transported. Each piece, made of high-density EPS, was coated with a spray to maintain the details and layers of resin and bright white paint. *The Magic Flute* resulted in a huge piece, with a total height of 10 meters, a width of 12 meters and a depth of almost 8 meters.

Case study 2

Promotor	BCN3D Sigma	
Project	Caltatrava Turning Torso (Sweden)	
Objective	Tribute to Calatrava through a physical model of the building	
Equipment	Printers 3D BCN3D Sigma	
Beneficiary	Residents of the building created by Calatrava.	
Source	<u>Homenaje a Calatrava imprimiendo en 3D el Turning Torso (bcn3d.com)</u> <u>https://www.suntem3d.ro/</u>	

In 1999 the architect Santiago Calatrava was invited to build a residential tower for the Malmö area, a port area of Sweden. The project is a 190-meter tower that symbolizes the human body in motion. It is made up of 9 units (each of them five floors) rotated together and generating a spiral movement. It is the second tallest building in Europe.


Case study 3

Promotor	Afgan Rehabilitation Group. The architects of Ozod-Seradj's Architects Seradj+ architecture studio	
Project	Buddhas of Bamiyan (Afghanistan)	
Objetive	To restore the Awesome Buddhas destroyed by the Talibans	
Equipment	<u>ProJet 3D printer with ColorJet® technology</u>	
Beneficiary	Afganistan	
Source	<u>unesdoc.unesco.org/ark:/48223/pf0000261517</u> <u>3D Systems' Geomagic Wrap and ColorJet 3D Printers Help Rebuild Afghanistan's Past 3D Systems</u> <u>ARG e.V. (arg-ev.de)</u> <u>Los budas de Bamiyán vuelven a la vida gracias a la tecnología (huffingtonpost.es)</u>	

In 2001 The Bamiyan Buddhas were destroyed by the Taliban. In 2009 they began planning the reconstruction of the Buddhas of Bamiyan, whose chambers were declared a World Heritage Site in 2003. The project is funded by a group of countries and organizations, led by UNESCO (United Nations Educational, Scientific and Cultural Organization) and ICOMOS (International Council on Monuments and Sites).

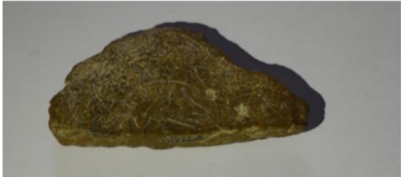
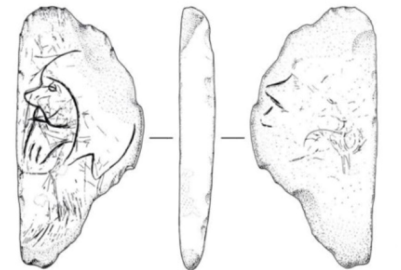
Using historic documentation and pictures the destroyed cave structures could be reconstructed by identifying original geometric features within the virtual 3D model. The AAchen Universiy underlines that there remains only 12% of the original materials. However, the ICOMOS mentions than there are 48%. Several intervention scenarios were described in detail during the international symposium on 'The Future of Bamiyan Buddha Statues', held in Tokyo in September 2007, and also before during the 12th meeting of the Expert Working Group on Bamiyan held in Orvieto, Italy, in December 2013.

Case study 4

Promotor	PROJECT OF IaaC, Institute for Advance Architecture of Catalonia	
Project	Kakuma Refugee Camp	
Objective	Education programm 2019-2020	
Equipment	6-axis robotic arm	
Beneficiary	Refugees	
Source	https://www.iaacblog.com/programs/community-design/	


Around 200,000 people inhabit the Kakuma Refugee Camp in Kenya, which is more like a city than a temporary shelter. This proposal for Kakuma emphasizes security and privacy in terms of planning, density, materials, views, and the distinction between public and private spaces.

Case study 5

Promotor	The Laboratory of Photogrammetry of Iuav University of Venice and the Archeological Museum of Massa Marittima	 <p>Figure 1: Uomo barbuto di Vado all'arancio</p>  <p>Figure 2: Drawings of the limestone slab (after Martini 2016)</p>
Project	Uomo barbuto di vado all'Arancio	
Objective	Production of a path accessible to blind people through audio-tactile works	
Equipment	Multi-image photogrammetry, TOF laser scanner.	
Beneficiary	GaMHer Project	
Source	<p>Uomo barbuto di Vado all'arancio. REPLICAS IN CULTURAL HERITAGE: 3D PRINTING AND THE MUSEUM EXPERIENCE M. Ballarin 1*, C. Balletti 1, P. Vernier1</p> <p>The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLII-2, 2018 ISPRS TC II Mid-term Symposium "Towards Photogrammetry 2020", 4–7 June 2018, Riva del Garda, Italy</p>	

	https://isprs-archives.copernicus.org/articles/XLII-2/55/2018/isprs-archives-XLII-2-55-2018.pdf
<p>Archaeological finding of the upper Palaeolithic (11.600 years B.P.) named “Uomo barbuto di Vado all’Arancio” (Bearded mad of Vado all’Arancio). It is an engraved limestone slab found near Massa Marittima (GR) (Martini 2016) n the main face we can still see his nose, his eye, his long moustache, his straight and thin mouth, his beard and what could be his hair or a headgear. On the opposite side, there are still traces of a possible human face, but the drawing appears incomplete (fig. 1-2). The size of the object is very small: its dimensions are 8.2x4.1x1.1 cm.</p> <p>We produced four test copies: three using the same machine but different materials, and the fourth one using a printer that can create fully colored replicas. The technique chosen is Selective Laser Sintering (SLS): it is a technique which uses a laser as a sintering source of a thermoplastic powder: thin layers of dust of different materials, such as polycarbonate, nylon, ABS, are laid down progressively and consolidated, where necessary, by the laseR. An EOS Formiga P395 was used to print the two white copies, which were made of plastic material (Nylon). It was the software Geomagic Studio (Geomagic).</p>	

Case study 6

Promotor	Madrid Naval Museum	
Project	Accesibility Space for Visual Problems	
Objective	3D Printed Braille Devices for visual and cognitives deficiencies	
Equipment	3d printers	
Beneficiary	Tourist with disabilities	
Source	<u>Accesibilidad - Instituto de Historia y Cultura Naval - Armada - Ministerio de Defensa - Gobierno de España</u>	

Development of customized braille readers and other assitive devices using 3D printing. The museum offers four tactile stations with raised text and Braille:

1. Nautical Instruments. Unit 2: The Age of Discoveries. 15th and 16th Centuries.
2. The First Circumnavigation. Unit 2: The Age of Discoveries. 15th and 16th Centuries.
3. The Ship of the Line. Monograph B: The Golden Age of Naval Construction in the 18th Century.
4. Chinese Porcelain from the San Diego Galleon. Monograph C: The Defense of Trade Routes in the 16th and 17th Centuries.

A free app with an audio guide for the permanent exhibition is provided by the museum, which includes audio descriptions for Android and Apple devices. Regular activities are provided to visitors with visual impairments by specialized professionals.

Hearing Accessibility Services: A free app from the museum that includes an audio guide for the permanent exhibition and subtitles and Spanish Sign Language (LSE) is available for Android and Apple devices. Activities for visitors with hearing impairments are conducted by specialized professionals and LSE interpreters on a regular basis. The museum's YouTube channel provides adapted content with LSE and subtitles.

Cognitive Accessibility Services: The museum provides a free app with an audio guide for the permanent exhibition, featuring an Easy Reading itinerary for Android and Apple devices. Visitors with intellectual disabilities are able to participate in regular activities provided by specialized professionals. The Naval Museum also offers an Easy Reading booklet with some of the most important episodes in naval history.

Case study 7

Promotor	National Museum and Memorial	
Project	Bespoke Bodies. The Design and Craft of Prosthetics	
Objective	Explore and showcase the evolution and innovation in prosthetic design. By featuring stories from diverse users such as professional athletes, veterans, children, and others	
Equipment	Printers 3d Prototypes	
Beneficiary	<ul style="list-style-type: none">– People with Disabilities– Tourist– Citizens	
Source	https://theworldwar.org/bespokebodies	

Bespoke Bodies: The Design & Craft of Prosthetics explores the past, present, and future of prosthetic design. The exhibition features stories from professional athletes, veterans, children, and other users who collaborated with prosthetists and designers to create prostheses with improved functionality, comfort, adaptability, and aesthetics.

The exhibit emphasizes the integration of prosthetics within broader narratives of technology, medicine, and personal stories. It includes interactive stations where

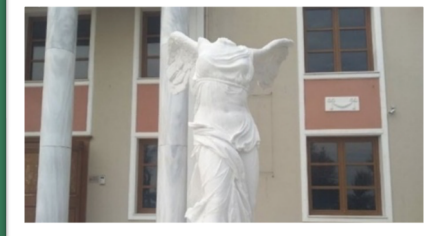
visitors can experience VR devices and 3D-printed prototypes. Notable figures like fashion model Kelly Knox and philanthropist Lauren Scruggs Kennedy are featured, along with everyday individuals who have significantly contributed to the field.

Case study 8

Promotor	Lewis Yakich, Material Engineer	
Project	Philippines' <u>Lewis Grand Hotel</u>	
Objective	Built a 3d hotel cheaper and faster	
Equipment	ECOLOGICAL MATERIALS 3D PRINTERS	
Beneficiary	TOURISTS	
Source	<u>Manila's Lewis Grand Hotel Unveils The First 3D-Printed Hotel Room (forbes.com)</u> https://3dprint.com/94558/3d-printed-hotel-lewis-grand/	


The villa – which measures 10.5 meters by 12.5 meters and stands three feet high – includes two bedrooms, a full living room, and a jacuzzi room with a 3D-printed spa. The suite – a 130-square-meter (~1,400-square-foot) spread entirely made of concrete – is the first legally sanctioned and operational commercial structure in the world created using 3D-printing technology. Part of the hotel's ongoing expansion, the villa – which measures 10.5 meters by 12.5 meters and stands three feet high – includes two bedrooms, a full living room, and a jacuzzi room with a 3D-printed spa.

Case study 9

Promotor	Elias Kyriakides	
Project	Nike de Samotracia	
Objective	The goal was to create an exact replica of the piece that is exhibited in the Louvre for the city.	
Equipment	3d printer and marble robotics machines	
Beneficiary	Evros Local and regional government	

Source	https://greekreporter.com/2019/03/15/nike-of-samothrace-replica-awaits-transfer-to-greek-island-home/
<p>The Louvre Museum has several initiatives related to 3D printing and replicas of its artworks. A notable example is the exact replica of the statue of Nike of Samothrace. This replica was created from a 3D digitized archive provided by the Louvre and was sculpted in marble from the island of Thassos. The replica is temporarily located in Alexandroupolis before being transferred to the island of Samothrace (GreekReporter.com).</p> <p>Additionally, the Louvre offers virtual tours and online activities that allow you to explore the museum and its collections from home. Although 3D printed replicas for public acquisition are not specifically mentioned, the museum has an online store where you can find various objects related to its exhibitions, including some reproductions (Le Louvre).</p> <p>For more information about these initiatives and to explore the museum's digital offerings, you can visit its [official website](https://www.louvre.fr/en/online-tours) and [online store] (https://boutique.louvre.fr) (Le Louvre).</p>	

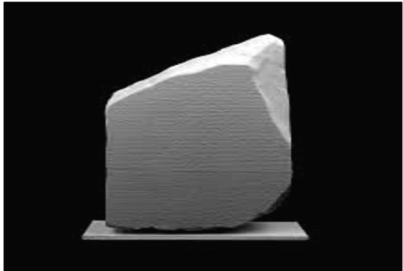
Case study 10

Promotor	Oren Geva	
Project	Camera 2c3d	
Objective	Help Perceive Objects to Blind People	
Equipment	3D Printers	
Beneficiary	Blind People	
Source	La Cámara 3D Diseñada Para Los Ciegos (Elnortedecastilla.Es)	

Ren Geva designed a camera specifically for the blind and visually impaired population. This camera serves its purpose by utilizing 3D pixels that rise to create a relief, representing the shape of the photograph being taken. In this way, individuals who cannot see the photo can perceive it tactually, gaining an idea of its content.

Geva was inspired to create this innovative camera by Pin Toy Art, a toy designed in 1987 that featured a box filled with plastic pins that could be pushed in to form shapes on the box's surface. The camera operates on a similar concept, where the relief is formed based on the photograph taken, allowing tactile perception instead of visual.

Case study 11


Promotor	British Museum	
Project	3d Stone Slab	
Objective	The objective of uploading the 3D model of the Rosetta Stone to Sketchfab by the British Museum is to enhance accessibility and engagement with this historically significant artifact	
Equipment	3d Printers	
Beneficiary	Tourists	
Source	https://hyperallergic.com/391501/rosetta-stone-3d-model-british-museum/ https://www.britishmuseum.org/collection/egypt/explore-rosetta-stone	

In July 1799, a group of soldiers stumbled upon an object set to change our understanding of the ancient world.

That object was the Rosetta Stone, perhaps the most famous piece of rock in the world. This fragment of an ancient stela (an inscribed slab) became the key that unlocked the mysterious hieroglyphic script of ancient Egypt.

This scan was part of a larger attempt to capture as many of our iconic pieces from the collection, and indeed the unseen in store objects, and make them available for people to view in 3D or in more tactile forms.

Case study 12


Promotor	Apiscor	
Project	3D Houses	
Objective	Built 3D Economical Houses in 24 Hours	
Equipment	Printer 3D Apis Cor	
Beneficiary	Customers	
Source	<u>Startup 3D: Apis Cor, imprimiendo casas en 3D - 3Dnatives</u>	

The company is the creator of one of the mobile construction 3D printing technologies, enabling the mass use of additive technologies directly on construction sites and capable of competing with traditional methods. The printer prints walls and partitions on-site to create the entire building.

The Apis Cor 3D printer constructs entire buildings directly on construction sites while being mobile and transportable using conventional construction machinery. The printer has a small footprint, making it easily transportable by a standard truck and requiring minimal preparation time before starting construction. All preparatory work takes no more than 30 minutes. Another advantage is the absence of construction waste. By staying in one place, the Apis Cor 3D printer can create walls layer by layer using a concrete mix, covering a total area of 132 square meters.

The building frame can save up to 25-40% in construction costs when using this technology instead of traditional construction. This is achieved through minimizing manual labor, automating the process, and reducing the construction time of a typical single-story house to a couple of days, as well as decreasing the amount of material required for printing wall structures. Apis Cor's 3D printing solution is a technology that allows for printing an entire house anywhere within 24 hours.


Case study 13

Promotor	Thinking Huts	
Project	3D Printed Schools in Madagascar. Bougainvillea	
Objective	Create Schools to Connect People	
Equipment	3D Printers	
Beneficiary	Children	
Source	https://www.designboom.com/architecture/thinking-huts-3d-printed-school-madagascar-fianarantsoa-06-06-2022/ https://www.forbes.com/sites/jenniferhicks/2022/07/21/here-is-a-3d-printed-school-in-madagascar/#:~:text=In%20April%202022%2C%20the%20city,weeks%20to%20complete%20the%20structure	

The 3D-printed school architecture in Madagascar was based on the honeycomb vision of Maggie Grout, founder and CEO of Thinking Huts (see more here). Local construction was managed by SECOA. The school's 3D-printed walls are made of a cement mixture that withstands environmental pressures. The roof, door, and windows are made from locally sourced materials. Local manufacturers are involved in the construction process of this hybrid design while teaching 3D operational skills for future projects. The responsibility of overseeing daily

operations, maintaining, and providing teachers falls on trusted local partners. Madagascar was chosen due to personal connections on the ground, local support, an estimated need for over 22,000 schools due to overcrowding and long travel distances, as well as opportunities for solar energy.

Case study 14

Promotor	Medialab. Metropolitan Museum of Art	
Project	Edible Met: Eating Art to Understand	
Objective	To create 3d eating printed of cultural heritage	
Equipment	3d printed food	
Beneficiary	The Metropolitan Museum of Art	
Source	The Metropolitan Museum of Art (metmuseum.org) https://www.metmuseum.org/about-the-museum/museum-departments/office-of-the-director/digital-media-department/medialab	

The MediaLab is seeing how ancient techniques reassert their relevance in contemporary digital artistic practice. While low-cost 3D scanning and printing provides new opportunities for creative engagement with museum collections, traditional casting methods allow artists to incorporate a much broader range of materials into their work.


We initiated our project by downloading 3D models from the Met's Thingiverse page, editing them using Tinkercad, and printing them with 3D Systems' CubePro 3D printer in the MediaLab. We were interested in creating a multisensory experience so that our visitors can touch, smell, and even taste artworks in the Museum.


Case study 15

Promotor	Urban Intervention	
Project	Lanterns	
Objective	Lighting up the streets	
Equipment	Ultimaker S5	
Beneficiary	Citizens and tourists visiting Belfast	
Source	Utilizan la impresión 3D de forma sostenible para iluminar las calles de Belfast - 3Dnatives https://urbanscaleinterventions.com/	

The final idea chosen was to create an ocean of suspended orbs, reminiscent of the region's maritime heritage. 3D printing allowed USI to adapt, modify, and utilize various design options for the pieces. Located in Belfast, Northern Ireland, the Wine Cellar Entry is one of the spaces transformed with the help of 3D printing. This was made possible by Urban Scale Interventions (USI), which initiated an urban lighting project based on citizens' needs and preferences. After consulting the community, four clear co-design principles were identified: sustainable, playful, interactive, and safe experiences. The project aims to create a floating ocean of 3D-printed orbs to illuminate this hidden gem of Belfast's mercantile history.

Case study 16

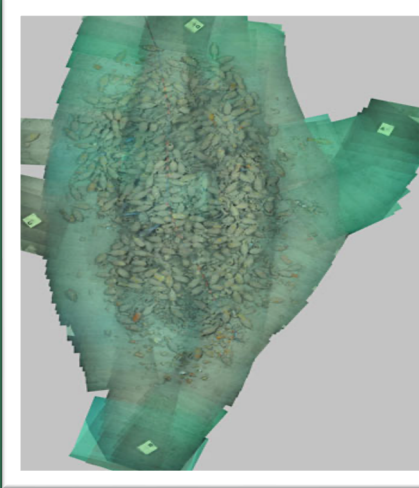
Promotor	Swedish Pompeii Project, supported by Parco Archeologico di Pompei, Digital Archaeology Laboratory (DARKlab), Humanities Lab at Lund University, Fil dr Uno Otterstedts fond, Bokelunds resestipendiefond	
Project	Virtual Reality Reconstruction of Pompeii's House of the Greek Epigrams	
Objective	To investigate the perception and manipulation of views in Roman domestic spaces using virtual reality and eye-	

	tracking to understand how these spaces influenced social identity	
Equipment	Virtual reality (VR) headsets, eye-tracking technology, geographic information systems (GIS), 3D modeling software	
Beneficiary	Archaeologists, historians, educators, students, visitors to Pompeii, and researchers in cultural heritage and ancient Roman history	
Source	https://www.journals.uchicago.edu/doi/10.1086/731330	

Results showed that human perception within these spaces was dynamic, influenced by body movement, light, and proximity. In the atrium, participants moved in circular or L-shaped patterns to engage with the painted medallions, suggesting non-linear viewing pathways that reinforced social rituals. In the peristyle, lighting conditions greatly affected how participants perceived the intricate wall paintings, with details emerging as they moved closer. The study also revealed that the room with the epigrams was better experienced through dynamic movement rather than static sitting, as proximity allowed for better interpretation of the painted scenes and inscriptions.

The research highlights how ancient Romans used views to structure social identity and how architecture and decoration manipulated sensory experiences to create complex visual and ritual engagements in their homes.

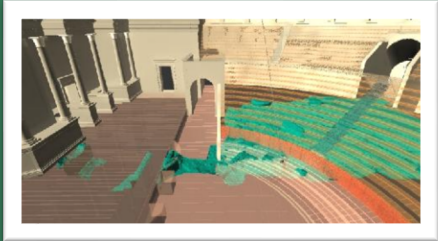
Case study 17

Promotor	European Community. "Information Society Technologies (IST) programme of the 6th Framework Programme for Research and Technological Development (FP6).	
Project	The VENUS project (Virtual Exploration of Underwater Sites)	
Objective	It creates immersive environments for archaeologists to study these underwater sites and	

	for the general public to experience simulated dives, all while promoting digital preservation of cultural heritage	
Equipment	VCR.	
Beneficiary	Archaeologists, researchers in cultural heritage, and the general public interested in exploring and preserving underwater archaeological sites	
Source	https://archaeologydataservice.ac.uk/archives/view/venus_eu_2009/ https://dl.acm.org/doi/10.5555/2140572.2140574 VENUS: Virtual ExploratioN of Underwater Sites: Port-Miou C wreck, Marseille Pierre Drap, 2009. https://doi.org/10.5284/1000004	

It focuses on the virtual exploration of shipwrecks at various depths, using advanced sonar and photogrammetry techniques. A key case study involves the digital reconstruction of shipwreck sites, which are otherwise inaccessible to divers. Through virtual and augmented reality, the project . In this case is Marseille.

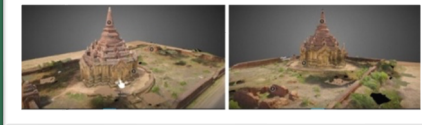
Case study 18

Promotor	Polytechnic University of Marche, Department of Civil and Building Engineering and Architecture, Ancona, Italy	
Project	Virtual Reconstruction of Lost Architectures: A case study focused on the Fano Roman Theatre, using AR/VR technologies for digital reconstruction	
Objective	To virtually reconstruct lost Roman architectural structures, specifically the Fano Roman Theatre, and	

	make it accessible through AR and VR platforms for educational and cultural dissemination	
Equipment	Terrestrial Laser Scanner (TLS), 3D modeling software, AR platforms, Google Cardboard, LIDAR	
Beneficiary	rchaeologists, historians, students, tourists, and cultural heritage institutions	
Source	Virtual Reconstruction of Lost Architectures: From the TLS Survey to AR Visualization" from the International Archives of Photogrammetry, Remote Sensing, and Spatial Information Sciences. https://isprs-archives.copernicus.org/articles/XLI-B5/383/2016/isprs-archives-XLI-B5-383-2016.pdf	

The main results of the project highlight the feasibility of using 3D scanning (TLS) and AR/VR technologies to digitally reconstruct the Roman Theatre of Fano. The reconstruction combines point cloud data and historical sources, ensuring geometric accuracy while creating a detailed virtual model. The project succeeded in making the architectural structure accessible through immersive experiences, benefiting both experts and the public. Despite challenges in visualizing complex 3D models on mobile platforms, the study demonstrates the effectiveness of integrating AR and VR for cultural heritage dissemination.

Case study 19

Promotor	CyArk, with collaborations including UNESCO	
Project	Virtual reconstruction of Ayutthaya's historical heritage sites, focusing on grand temples and palaces.	
Objective	To digitally preserve Ayutthaya and provide immersive, accessible virtual tours for educational and research purposes.	
Equipment	3D modeling, VR platforms (HTC Vive, Oculus Go,	

	Oculus Rift), photogrammetry, and spatial data documentation	
Beneficiary	Scholars, students, tourists, and global users interested in cultural heritage.	
Source	https://heritagesciencejournal.springeropen.com/articles/10.1186/s40494-024-01403-1	

Virtual tours of Ayutthaya’s heritage sites with educational tools and guided navigation options. The Ayutthaya project successfully created immersive and interactive 3D models of its UNESCO World Heritage sites, allowing users to virtually explore its historical architecture, temples, and palaces. The digital preservation enhances accessibility for a global audience, supports education, research, and heritage management, and helps preserve cultural knowledge. By offering guided tours and immersive experiences, it increases engagement with heritage sites. The project also demonstrated the integration of VR and AR technologies, ensuring these heritage sites are preserved digitally for future generations..

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