The MUSETECH model: A Comprehensive Evaluation Framework for Museum Technology

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Digital technologies are being introduced in museums and other informal learning environments alongside more traditional interpretive and communication media. An increasing number of studies has proved the potential of digitally-mediated cultural heritage experiences. However, there is still a lot of controversy as to the advantages and disadvantages of introducing the digital into museum settings, primarily related to the risks and investment in terms of time, human and financial resources required. This work introduces the MUSETECH model, a comprehensive framework for evaluating museum technology before and after its introduction into a museum setting. One of the unique features of our framework is to consider the evaluation of digital technologies from three different perspectives: the perspective of the cultural heritage professional, the perspective of the cultural heritage institution and the perspective of the museum visitor. The framework benefited from an extensive review of the current state of the art and from inputs from cultural heritage professionals, designers and engineers. MUSETECH can be used as a tool for reflection, before, during and after introducing novel digital media resources. The model covers technologies as diverse as mobile museum guides, Augmented and Virtual Reality applications, hands-on museum interactives, edutainment applications, digitally-mediated tangible and embodied experiences or online approaches used for museum education and learning.

CCS Concepts: • **Information Interfaces and Presentation → User Interfaces; • Computer Applications → Arts and Humanities.**

General Terms: Design, Human Factors

KEYWORDS
Museums, Cultural Heritage, Evaluation, Digital Heritage, Interactivity, interaction design, usability, user experience

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1 INTRODUCTION

The early 21st century saw a turn towards increasingly diversified uses of the digital in museums and heritage institutions for research, documentation, education, communication and outreach purposes. Today, it is inconceivable to imagine a museum or heritage site not making any use of technology. The technology range itself is vast, from databases, museum websites and digital ticketing systems to digital interactive exhibits and installations, mobile applications, virtual museums or communication over social media networks.

Despite this widespread "digital reform", it is still difficult to assess the various dimensions of the impact on museums as institutions, museum staff and visitors. How do museums and other cultural heritage institutions employ museum technology? What is the long and short-term impact for communicating and marketing tangible and intangible heritage within museums, heritage sites and public memory institutions? Which skills and competencies are required to make successful use of technology? How does that alter the practices for cultural heritage professionals? How and why can technology make a difference for the visitor experience?

The rich body of research literature (Tallon and Walker 2008; Parry 2010; Ciolfi 2018), audience research (Kelly 2016; Villaespesa 2016; Damala et al. 2016b) and contemporary museum practice resources (Simon 2010; Phillips 2016; Simon 2016) points towards the potential of digital technology for a wide range of museum goals, such as education, enjoyment and learning, in ways that support first-person, experiential, interactive, embodied and often deeply emotional experiences. Yet we still know surprisingly little about how museum audiences interact with and make sense out of experiencing heritage through digital means. Conversely, it is widely known by those museum professionals and researcher who have invested in bringing a museum technology program to life that the introduction of the digital comes with a complicated series of factors influencing its implementation and success. The risks associated with new technology are often difficult to assess while considerable investments in time, human and financial resources are needed for its introduction (Vom Lehm and Heath 2005).

Developing appropriate evaluation standards, benchmarks, guidelines and frameworks so as to more successfully design, deploy, and maximize the impact of the digital would be a welcome step forward. However, evaluation still counts as one of the most important challenges cultural heritage professionals and museum institutions are faced with. A 2015 report notes that "while many museums are astute at assessing their traditional programs, they have yet to cultivate standard protocol for measuring the success of the technologies they deploy" (Johnson et al. 2015).

This paper introduces the MUSETECH model, an evaluation framework with multiple components that can assist museums, heritage institutions and heritage professionals in successfully planning for and managing the deployment of digital technology.

The paper is structured as follows: Section 2 sheds light on the different terms employed to talk about the use of digital in the museum, i.e. museum technology and its assessment and evaluation. Section 3 looks into contemporary key trends in the evaluation literature, offering a novel classification of research resources. It also examines influential theories that have been articulated around this framework's three main entities and perspectives: The Cultural Heritage Professional (CHP), the Museum and the Visitor. Section 4 is dedicated to the methodology developed in order to gather the raw data from which the model emerged. Section 5 details all building blocks and working definitions of the proposed framework, providing a high-level overview of the Evaluation Criteria (ECs) identified by the technology introduction phase. For clarity, the full-fledged version of the Matrix, with a presentation of all 121 ECs, is provided as a separate digital resource, available in conjunction with this paper. This separate document, the "Companion", accompanies the present publication and is meant to be a practical, A to Z guide to MUSETECH, the Matrix and all identified ECs. Following the overview of the Matrix and its components, section 6 provides three use-case scenarios, demonstrating the flexibility of the model for discussing evaluation and assessment of museum technology. Section 7 discusses the advantages and limitations, and highlights directions for future work, while section 8 summarises the most important take-away messages for museums and Cultural Heritage Professionals, researchers and practitioners.

2 A NOTE ON TERMINOLOGY

2.1 Defining Museum Technology

The number of terms used in the museum literature for discussing the digital is staggering and indicates the many ways digital technology is approached and understood in heritage settings (Dierking and Pollock 1998; Adams et al. 2004). "Digital media", "digital heritage resources", "museum interactives", "virtual museums", "digital humanities", "digital heritage", "digitisation", "digital cultural resources", "digital curation", "digital engagement", are only some of the umbrella terms used to essentially describe the use of technology for activities as diverse as cataloguing, documentation, preservation, communication, education, dissemination and outreach in online and onsite heritage settings.

The array of existing technologies is equally amazing: online ticketing systems; Content Management Systems; online exhibitions; online museums; digital heritage representations and experiences in Virtual and Augmented Reality; museum websites; mobile museum sites; 3D reconstructions; tangible exhibits; interactive tabletops; digital audio guides; digital multimedia guides; digital citizen science and crowdsourcing; and social media.

Things evolve so quickly that even terms usually associated with one type of technology can prove to be misleading. For example, the term "virtual museum" was recently reported as having grown "to become an all-encompassing term, referring to all types of digital representations of both digitized physical objects and born-digital ones that can be related to the physical objects" (Perry et al. 2017). Viewed from this perspective, an online exhibition is as much a virtual museum as a serious game played on a mobile device or an interactive table-top installation. The cross-fertilisation of the many underlying disciplines, such as museum and visitor studies, interaction design, user experience or digital humanities can also be hold responsible for that (Antoniou et al. 2013; Ciolfi 2018). For example, the term "digital humanities" (Ross 2018), predominantly used to flag the use of the digital in the Arts and Humanities for research or formal education purpose, does not exclude uses in informal learning environments such as museums and galleries. A 2014 publication from the European Commission (2014) examines the term "digital heritage" alongside the established terms "tangible" and "intangible" cultural heritage. In doing so, it demonstrates how pervasive and intertwined the digital is with how we experience cultural heritage.

Within this work and in order to bypass all disambiguation, we favoured the use of the term "the digital" and "museum technology" as umbrella terms that are wide enough to cover any type of technology applied in museum and heritage settings. Other terms are used when necessary (mobile learning, games, AR or VR, museum interactives, etc.) to denote and convey key trends and ideas in deploying and evaluating specific types of museum technology. Having clarified that the term "museum technology" is wide enough to be used for making reference to any type of technology, installation, application or digitally mediated museum experience, it is time to examine what "evaluation" stands for in the museum environment and why this is important alongside the term "museum technology".

2.2 Defining Evaluation

Evaluation is about finding out - using a variety of approaches, tools and methodologies - what works, as well as identifying what can be improved. The definition given by the US Government Accountability Office defines evaluation as a "systematic study using research methods to collect and analyse data to assess how well a program is working and why" (GAO 2012). We find this definition perfectly valid for museums and heritage institutions. The "when", or at which phase this may occur, is discussed in the relevant literature: when evaluation is carried out at the very early stages of a project, providing feedback about future activities and planning, we talk about front-end evaluation (Dierking and Pollock 1998); formative evaluation on the other hand occurs while a program is still in development (Economou 1998); the term "remedial evaluation" is used to designate evaluation occurring for troubleshooting, once a program has been already launched (Diamond et al. 2016). Finally, summative evaluation is carried out once a program has been completed and set

in motion (Davies and Heath 2014). In all cases, evaluation is said to have two main purposes: 1. proving or demonstrating if "change" is taking place, and 2. improving, seen as a constant reflection on further development (HLF 2012).

While the "when" of evaluating museum technology seems pretty clear, the "what" of assessment, evaluation or measurement when museums make use of technology has yet to be systematized because of its breadth, scope and complexity. The number of variables one can take under account is dazzling: selecting the appropriate technology; adapting it to fit the goals; create, update and reuse content; personalise, monitor and tweak in order to guarantee robustness and flawless performance; understand the impact on the work-flow processes for the museum personnel; proceed to a cost-benefit analysis; infer whether staff training is required; investigate energy and maintenance issues; guarantee security and safety; manage and guarantee accessibility for all visitors; manage personal data storage and usage; these are only some of the usually "hidden" performance and efficiency metrics that may be important for museum professionals and heritage institutions alike when it comes to successfully deploying museum technology.

However, the list does not end there: while these questions are still under investigation, subtler and less measurable aspects come into view, related to the way museums, objects, exhibits and narratives are experienced. Such aspects cover utility, usability and the user (visitor) experience, both onsite and online; intuitiveness and enjoyability; distraction and isolation hindering the encounters with the real exhibits; interactions with other distant or co-located visitors; managing to link the pre-, during- and post-visit phases in order to establish long-term relationships with the visitors; creating meaningful, personal, relevant, captivating narratives for various visitors' profiles. The list seems to be endless. Where should one start from? How exactly to proceed?

3 EVALUATING MUSEUM TECHNOLOGY: LITERATURE AND MUSEUM PRACTICE TRENDS

3.1 Typology of Publications and Resources

In attempting to systematize the existing body of knowledge in evaluating museum technology we identified five different types of publications and resources, focusing on different aspects of the use of technology in museums.

1. **Museum technology studies and reports.** These usually focus on one type of technology applied in the museum environment. They often examine the use of one implemented program, usually at the same institution, focusing on one type of technology such as digital audio and multimedia guides (Tallon and Walker 2008), interactive tabletops (Hornecker 2008), Augmented Reality (Damala and Stojanovic 2012), Mixed Reality (Benko et al. 2004) or Virtual Reality (Kassahun et al. 2018), tangible and embodied interaction (Petrelli et al. 2014).
2. **Museum, visitor, audience research studies.** These studies have a focus on visitor studies and audience research, scrutinising the complex processes of meaning-making in heritage environments. As they often examine the success of museum programs -which may not necessarily make use of technology- they are invaluable in finding out what worked and what not. Influential models and studies include the interactive museum experience model of Falk and Dierking (1992), the Generic Learning Outcomes (Hooper-Greenhill 2004), the five visitor identities identified by Falk (2009), the ant-grasshopper-fish-butterfly visiting styles of Véron and Levasseur (1989) or the application of the theory of flow to museum visiting (Csikszentmihalyi and Hermanson 1999).
3. **Technology watch reports.** These are a distinct category of usually non-academic publications, providing advice and, often, hands-on examples, examining key trends; often, however not going very deep and without being exhaustive. Representative examples include the Google Economist Report (McCauley 2016), the New Media Consortium Horizon Reports Museum Edition (Johnson et al. 2015), the "Museums and the Digital Revolution" report (Benhamou and Jarvis 2014) and others.
4. **"How-to" resources.** These may incorporate elements of technology watch and museum technology resources, borrowing from different disciplines and offering practical, how-to advice on specific issues on

evaluation, audience research or museum practice, including the use of museum technology (Gammon and Cutting 2008; Davis and Featherstone 2011; McIntyre 2014).

5. **Project-specific resources and public deliverables.** These are large or smaller research or museum practice projects which offer summaries, reports, publications or project deliverables. Recent projects include work on Virtual Museums carried out by the Virtual Museums Transnational Network (Pescarin 2014); the use of mobile devices and platforms for cultural heritage engagement and participation of PLUGGY, Pluggable Social Platform for Heritage Awareness and Participation (Lim et al. 2018); the potential of emotional storytelling explored by the EMOTIVE project (Economou et al. 2017a) or exploring the impact of new media on the affective experience of museum audiences investigated by the "New Media, Audiences and Affective Experience" project (Ntalla and Vom Lehn 2014) the use of Augmented Reality for underwater archeology, i-mare culture (Liarokapis et al. 2017); the use of technology for documenting and communicating intangible cultural heritage, the main goal of the i-treasures project (Volioti et al. 2018). The list is only indicative and is growing each year.

Though this categorisation may prove useful in navigating and identifying museum technology resources, it is also indicative of the complexity and fragmentation around designing, deploying and evaluating the use of technology in museums.

3.2 Models and Frameworks

Despite this observed fragmentation, frameworks, guidelines and lessons learned that could govern the use of museum technology can be identified both in literature and contemporary museum practice. This section examines influential theories and models that informed our work. Whenever possible, we extrapolate to other uses and applications than the ones put forward by the examined publications and resources, provided these can be meaningfully associated with the use of museum technology.

The "Digital Engagement Framework" (DEF) proposed by Visser & Richardson (2013) models how to successfully invest in online audience engagement and is in our opinion the most clearly articulated museum technology framework. The DEF provides 10 building blocks that assist in asking "the right question, at the right time", while in the process of setting up a digital strategy. These evolve around an institution's "assets" and a "reach" process allowing making new connections with a new or existing "audience". Once the audience has been reached, the "information", "technology" and "processes" blocks, inform and shape the "engagement" process. For this to succeed, specific and measurable "objectives" are put forward, shaped by a "vision" about the organisation, while taking into consideration various "trends". In addition to the value of the abstraction the model offers, the DEF comes with examples and worksheets which exemplify how it can be used in practice. Along the same lines, the Culture 24 "Let's Get Real" reports evolve around the digital and online engagement, featuring cross-institutional collaboration of UK and -in some cases- North American institutions around specific themes, in phases. From measuring online success (Finnis 2011) to understanding and measuring digital engagement (Malde et al. 2014), creating and curating digital content (Malde and Finnis 2015) and narratives (Malde and Finnis 2016), branding the online museum (Finnis et al. 2017) or understanding the social purpose of digital technologies for museums (phase 6, currently in progress), all reports are filled with many practical, real-life examples.

Though these works offer insights on whether online engagement can be directly translated to increased onsite attendance, they do not examine the multifaceted embodiment of museum technology on the gallery floors and the way it is experienced during an onsite visit. Conversely, some of the earlier resources in the field relate to onsite museum interactives or interactive exhibits (Bitgood 1991; Economou 1998; Falk et al. 2004; Adams et al. 2004), broadly defined as "computers and other multimedia components, physical manipulatives (including whole-body and tabletop activities) and simulations" (Falk et al. 2004). The term hands-on is also often interchangeably used with interactive, though often not involving technology. For Bitgood (1991), "control devices and response feedback mechanisms" play a critical role in defining whether an exhibit is hands-on or interactive: if the visitor's response results to a change in the exhibit, it is more correct to use the term interactive rather than hands-on. This 1991 publication also puts the term "device" in

the picture, albeit in a sense much different than the one used nowadays. Since then, reality and technological advances have made the term grow to include a large variety of devices, shared or personal displays, embarked interactive applications and corresponding cultural heritage experiences.

In addressing how to connect learning in the classroom with learning in museum galleries, through the use of mobile devices, Vavoula and Sharples (2008) proposed the M3 evaluation framework, with the evaluation of technology switching from one level to another, in a broad enough way allowing application in other contexts: 1. A micro-level evaluation, at early stages, gives an emphasis on individual user activities and the utility and usability of a system. 2. A meso-level evaluation takes place during the implementation phase, once the technology is robust enough, examining the learning experience as a whole. 3. Finally, a macro-level once the technology is in place and used long enough, examines "the impact of the new technology on established educational learning practices and institutions". This 3-level evaluation is applicable to nearly any kind of technology supporting learning experiences in museums.

The M3 model can equally be applied to the taxonomy of digital skills and activities identified for CHPs by the current project "One to One" in the UK. 1. Activities for digitising collections and opening the records up to a wider public. 2. Activities focusing on web presence and social media 3. Exhibition, learning and outreach activities and 4. Operational management and communication activities. This categorisation is offered as part of work undertaken in order to provide a framework for "museum workforce digital literacy" (Parry et al. 2018). Though this is a useful classification, it is less helpful when attempting to understand the full spectrum of technology uses in museums and other heritage institutions.

A 2016 report commissioned by Google to the Economist's Intelligence Unit tried to examine "the progress cultural institutions have made towards using digital tools to improve and access to their offerings" (McCauley 2016). The report looked at how digitisation is "affecting visitor outreach and the work of professionals in the field as well as how it is being used to educate on culture". It also provides useful indicators and categories which further allow us to understand the breadth of scope and various functions of technology in museums. Research was carried out for 243 institutions from 22 countries using a scorecard. The "Cultural Digitisation Scorecard" collected scores for 45 indicators that can be regrouped under five categories: Website assessment, social media presence, interactive experience capacity, digital access to archives and digital educational initiatives. The report concludes that "Augmented and Virtual Reality, 3D Imaging, cameras on drones, interactive social media and data tools that convert smartphone photos to 3D models are some of the technologies expected to come into widespread use in the sector in the near future/medium term. Meanwhile, professionals recognize that a more immediate challenge is to ensure that their digital offerings can be consumed in all their richness on a mobile device – now the communications technology of choice in every part of the world". Though some categories are broken down in subcategories, others remain vague.

The occurrence of the word "content" in various descriptors and indicators in this report, is used to reveal various meanings and across various contexts such as "(adapted) educational content", "not available (content)", "basic" "medium" "advanced" content, "digital cultural (display)", "quality of content" (under the category "access to archives"), "video", "original video", "personal creation", "user-created", "cultural content", "multimedia content" (McCauley 2016). For an assessment report about the impact of the digital in arts and culture, this demonstrates how far we are from establishing a common vocabulary around evaluating the impact of the digital. If it is difficult to agree upon with each other about fundamental concepts around the use of technology in museums, how are we supposed to find common ground around collectively informing and keeping informed about how best to deploy technology in museums?

The virtual exhibitions literature has advocated that the design of online exhibitions needs to go through a series of decisions. It has also emphasized that "an explicit and established procedure is needed, such as which are the decisions to be made and who and how decides on design issues" (Antoniou et al. 2013). This holds true for any museum technology embodiment. This work attempts to provide a systematized approach on who affects the design of museum technology. It provides a detailed, comprehensive framework of what it is that needs to be decided or at least thought about and for whom. For that, the remainder of this section brings together influential theories that have shaped our understanding of the processes carried out by museums,

CHPs and museum visitors through the use of technology. We start with the main stakeholder, the visitor, and then we bring into the picture the Museum and finally, the Cultural Heritage Professional.

3.3 The Visitor

It has been said that the one of the biggest contemporary challenge museums are faced with is the "reconceptualisation of the museum-audience relationship" (Hooper-Greenhill 2000). The shift of museums passing from a state of "being about something to being for somebody" (Weil 1999) came together with a boom in audience research and visitor studies. Likewise, the concept of "museum education" started to be superseded by the most active, constructivist concept of "museum learning" (King 2016). Despite these steps forward, we are still far from reaching a consensus about museum visiting as a profoundly transformative experience. This kind of museum visiting-"learning", can be multifaceted, multisensory, multidimensional and occurring in different temporalities. This approach towards museum visiting as "learning" is starting to become synonym with the impact heritage and public memory institutions (museums, archives and libraries) have on individuals and societies alike. This kind of transformative experience (or "learning") can be "self-directed" and "open-ended", "focused and specific", or "unfocused and unspecific", producing diverse outcomes, both in the short and the long term (Falk et al. 2004; Hooper-Greenhill 2004). Using the digital for creating engaging, meaningful, personal and relevant learning and meaning-making experiences cannot afford not taking into account the recent trends, outcomes and findings in museum and visitor studies as well as in audience research.

The Learning Impact Research Project (LIRP) project proposed a system of five Generic Learning Outcomes for measuring learning in museums, archives and galleries: increase in knowledge and understanding, increase in skills, change in attitude or values, evidence of enjoyment, inspiration and creativity and evidence of activity, behaviour, and progression (Hooper-Greenhill 2004). When it comes to subjective measurement of "learning", this system can provide some useful insights for a wide range of approaches, contexts and environments including "learning" through technology in heritage environments.

This is a major breakthrough in how we approach learning and the visitor-audience experience in the post-museum (Hooper-Greenhill 2000) and post-digital era (Parry et al. 2018). It follows other important breakthroughs, models and learning theories that have greatly contributed in comprehending the complex relationship between museums and their public as well as the societies in which museums are grounded. Influential theories include the theory of flow (Csikszentmihalyi and Hermanson 1999); Huizinga's magic circle as a liminal, separate from reality, space in which learning through games, play and edutainment occurs (Astic et al. 2011); the interactive museum experience model (Falk and Dierking 1992); visitors' identities (Falk 2016); Hein's approach to meaningful object-oriented learning (2002); and various learning, cognitive and meaning-making theories that researchers and museum practitioners have experimented with in the museum environment (Antoniou et al. 2013; Damala 2007). In terms of museum practice resources, they culminated with Simon's concept of "relevance"; with this, she tried to draw our attention to the importance of meaning and relevance for engaging museum visiting experiences, providing several examples of how museums can make a difference in the life of the individuals and the communities in which they are grounded. If museum technology is to be successfully deployed in museum and heritage settings for serving societies and individuals alike, taking under consideration the complex meaning-making processes and mechanisms underlying our physical, intellectual, spiritual and emotional involvement with heritage is of paramount importance.

3.4 The Museum

Though we may have come a long way in understanding how visitor studies and audience research can inform the introduction of museum technology, making sense of what it means for heritage institutions to successfully or unsuccessfully deploy technology, needs to focus on all stakeholders. Dwelling on the museum visitor as the only "user" of technology within a heritage context does not help us see the whole picture. We believe that, in addition to studying the effect of museum technology on the museum visitor, we should focus

on the effect it has on Cultural Heritage Professionals and the Museum as a living, growing and evolving organism.

The "Spectrum of Audience Engagement" is a model of how museums attempt to engage with their public. It showcases different perceived roles and differently manifested "museum personalities" (McIntyre 2014). The spectrum of roles shows how museums perceive their role in relation to their audiences and society more at large. The European e-cult value project (E-CULT 2016) also tried to systematize such a theory: its vision paper on the use of technology in cultural heritage is clearly founded upon an "institutional" level. Following this first level, cross-institutional collaboration (Johnson et al. 2015, Davies and Heath 2014) may be at a regional, national or international level. Other key notions directly associated with the museum as an entity relate to the "mission and goals of the institution" (Davies and Heath 2014) and "institutional commitment" (Dierking and Pollock 1998, p. 23), expressed within an "institutional context" (Davies and Heath 2014). This happens under specific "institutional circumstances" that result in specific "choices put forward by the institution", following "overarching institutional policies" or an "institutional strategy", that will make use of "institutional cultures, operations, philosophies and assets" (Johnson et al. 2015), subject to the notion of "institutional accountability" (Davies and Heath 2014). This is particularly true when planning for and deploying museum technology: it is fundamental to understand how technological tools may correspond with the missions and goals of the museum before being deployed at a large scale.

Dialogues around the post-museum are also pertinent. The post-museum is seen as embracing multiple subjectivities and identities in the process of constructing knowledge rather than authoritatively transmitting them (Hooper-Greenhill 2000). It has been written that "meaning-making in the museum has always had a social and political dimension" (Bradburne 2008). We have never been closer to museums delivering more in terms of personal, group, local, societal, regional, national and cross-border impact (Bollo 2013; Museums Association 2017). This explains why harnessing museum technology is fundamental for institutional change and for delivering impact. A comprehensive museum technology evaluation framework should also look at what is important and why for the museum as a social, economic and public institution.

3.5 The Cultural Heritage Professional

Even though the impact of museum technology on institutions has been acknowledged, the impact on existing day-to-day workflows, digital literacy and other related skills for CHPs has only recently started to be acknowledged. The importance of the knowledge of the staff has already been acknowledged in visitor studies (Dierking and Pollock 1998). Parry et al. (2018) have argued that for the digital to become "'innate within a range of operations and definitions", the question of the experience of the CHP has to be addressed (Parry et al. 2018). As discussed in section 3.2, Parry et al. (2018) identified four types of museum activities around which a CHP will deploy digital skills: 1. Digitising collections and opening the records up to a wider public. 2. Web presence and social media activities. 3. Exhibition, learning and outreach activities and operational management and communication activities. They also report back from the "One by One" project which seeks to deliver "a transformative framework for museum workshop digital literacy". This project built upon the "Baltimore Principles", a 2014 initiative which tried to map the training needed for future museum staff. To date, we know that the introduction of technology comes with the requirement to provide relevant training, help staff keep up-to-date, make staffing adjustments and develop new workflows (Johnson et al. 2015).

Even though this is a useful approach to understanding how museum technology impacts upon the museum workforce and the heritage sector job market, the actual "voice" of CHPs on how technology impacts their everyday experience and workflows is still surprisingly silent. The experiential, personal, and by default subjective perspective of the CHP in understanding this technology impact has yet to come into the picture.

If we are to demystify the role technology plays for both museums and their public, it would be more productive to also scrutinize the perspective of the persons who are in charge for the daily design, deployment, operation, and continuous adjustment of technology for documentation, communication, management and administrative purposes. Until today, the topic seems to have only been approached from a digital skills and digital literacy perspective.

3.6 Bringing It All Together

The literature review we undertook brought to life a taxonomy of five different categories of resources and publications which can be used as inspiration for a cohesive, comprehensive evaluation framework. Having examined the term "museum technology" and established the existence of at least three symbiotic entities, the CHP, the Museum and the Visitor, we started considering whether we could use these notions as building and inquiry blocks. The meSch (material encounters with digital cultural heritage) EU-funded project provided fertile ground for our experimentations (Petrelli et al. 2014; Petrelli et al. 2016). meSch was funded on co-design principles in order to explore the potential of Do-It-Yourself (DIY) approaches, online data repositories and the internet of things for creating tangible, multisensory and embodied museum visiting experiences that aimed to integrate seamlessly technology. The co-design and DIY approach favoured a cross-disciplinary collaboration among designers, engineers, researchers, hardware and information specialists. It also put museum professionals working on documentation, digital project management and museum education at the heart of the design process. As meSch produced digital museum interactives, it was essential to create a unifying framework that could assist us in evaluating different examples of museum technology. To this end, a series of workshops dedicated to evaluating museum technology were organized. The key notions and elements brought to these workshops were the three entities –the museum, the visitor and the CHP– and their experience from utilising "museum technology".

4 METHODOLOGY

The framework was developed in two stages. Firstly, a workshop of meSch academics and museum professionals created raw data for the evaluation framework which was then iteratively refined and validated at a second workshop (section 4.1). Secondly, the framework was validated and refined against existing literature and numerous contemporary museum practice examples provided by cultural heritage specialists from museums, libraries, archives and academia, during four workshops organized by the ScotDigiCH project (section 4.2).

4.1 Workshops

The first workshop comprised eight participants (2 museum professionals with specific experience in interactive museum installations, 1 participant from a research institute specialising in digital technology, 5 academics with expertise in interactive systems, user studies and visitor experience). Many participants had mixed experiences, having worked in more than one role, and all had experience of evaluation in the context of museums.

Four different building and inquiry blocks (Cultural Heritage Professional, Museum, Visitor and Technology) were introduced based on the existing literature and frameworks. We then worked to identify components of an evaluation framework within each of these components.

Then participants were encouraged to brainstorm, gather and cluster different evaluation criteria under these categories. There were no initial restrictions on what could be considered an evaluation criterion. Instead, the goal was to list, based on participants' knowledge or background, what criteria may be useful to include in the framework (Figure 1).

Initially, all criteria were simply recorded. Cross-cutting criteria that could apply to more than one entity were listed multiple times. This resulted in a list of 162 criteria. This was followed by an interactive process of aggregation and differentiation; aggregation to unify criteria that had similar semantics and differentiation to identify where concepts had multiple meanings and therefore required splitting and clarification to ensure that there was an agreed meaning to each criterion. The final lists for each entity were then refined and cleared for redundancies and repetitions.

This initial framework was then presented at a 2nd workshop with 20 participants with museum studies and interactive systems experience including participants from three museums (the Allard Pierson Museum in

Amsterdam; Museon in The Hague; and Museo Storico Italiano della Guerra, in Rovereto, Italy). This exercise helped in validating and further refining all identified evaluation criteria.

Following the second workshop, the MUSETECH model was developed in the form of the MUSETECH Wheel as seen in Figure 2. During discussion, "Technology" was seen as the element which permeates the "experience" of the three main entities but not as an entity of the same level or type of abstraction as the CHP, the Museum or the Visitor.

Fig. 1. Devising the MUSETECH model, meSch workshop, Museon, The Hague, February 2015

4.2 Validation

The second stage in the creation of the model was to compare the results of our framework against the existing literature. The aim was to identify gaps in the MUSETECH model and ensure it is as comprehensive, detailed and exhaustive as possible, so as to include as many aspects, issues, questions or parameters which can be taken under consideration when working with the digital, throughout the full life-cycle of any given museum technology program.

Additional, first-person testimonies and data was provided thanks to the four workshops which occurred within the framework of the Scottish Network on Digital Resources Evaluation – ScotDigiCH project, funded by the Royal Society of Edinburgh (2015-2016), coordinated by the University of Glasgow (Economou 2016; Economou 2017b). More than 100 participants in total participated in these four workshops. Each workshop culminated in summary reporting on trends, challenges and shortcomings in the use of digital heritage resources. These were video-recorded[1] providing invaluable additional materials against which we could assess the framework.

We used all these resources to detect evaluation criteria and map them against our MUSETECH model. Most criteria were easily mapped; where the mapping was not clear, two of this paper's authors worked together to either clarify the mapping or introduced a new element to MUSETECH.

[1] The videos from the workshop and final conference are available on YouTube at https://www.youtube.com/channel/UC5QIbBpVSrde4SJTDmyPDcA

5 INTRODUCING THE MUSETECH MODEL

5.1 THE MUSETECH WHEEL

The framework was visualised as a wheel with technology at its core (Figure 2). Technology was at the core as an underpinning component to all perspectives. Around this, a ring, representing an orbit, was added, divided in three parts corresponding to the CHPs, museum and visitor entities. This representation reflected the team's main motivation: coming up with a tool that can assist in understanding the multifaceted impact of technology on visitors, museums and CHPs.

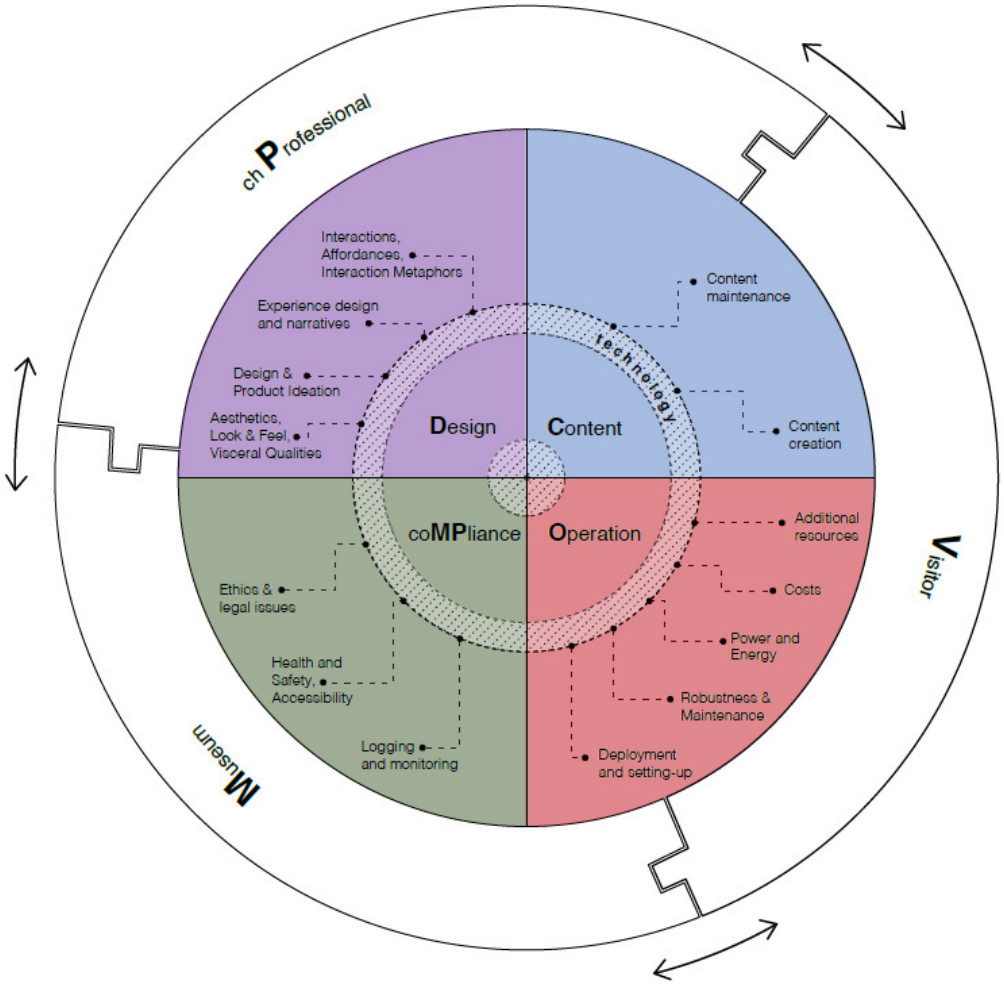

Fig. 2. The MUSETECH Wheel

5.2 QUARTILES AND CLUSTERS

Once Evaluation Criteria (ECs) were attributed to all three entities, we revisited the gathered data adding in a temporal dimension: in short, we started thinking about different constituents in the adoption and introduction of technology use in museums. Revisiting all ECs per entity separately and in a cross-comparative manner, resulted in the identification of four different constituents in museum technology: Design, Content, Operation and Compliance. All ECs were classified under one or more of these phases. The latter were subsequently modelled as four Quartiles (Design, Content, Operation, Compliance) set at the heart of the technology core of the MUSETECH Wheel and representing separate phases in the life-cycle of museum technology. Furthermore, while categorising data under the three perspectives and the four museum technology introduction Quartiles, further groups started to meaningfully emerge. This allowed us to create sub-groupings within each Quartile. We called these Clusters. All Clusters are visible within each Quartile in the Wheel (Figure 2).

Though this visualisation communicates that evaluating museum technology should be examined under the three identified perspectives (Visitor, Museum and CHP) throughout all four identified museum technology introduction phases, a more detailed map, visualisation and representation tool was needed, in order to match museum technology ECs under perspectives, quartiles and clusters. After many trials, a new tool emerged, the MUSETECH Matrix (see the "Companion", the additional resource offered in conjunction with this contribution and for a fragment of the Matrix, Figure 3). This allowed us to complement the Wheel by providing a detailed map with all ECs, regrouped by Cluster, Quartile and Perspective, as detailed in the next subsection.

5.3 THE MATRIX

The Matrix is essentially a table. Its first column corresponds to the "Technology" core of the Wheel. The other three columns regroup evaluation criteria (ECs) relevant to the CHP, the Museum and the Visitor.

The Matrix lists all 121 ECs and structures them by Perspective, Quartile and Cluster. Each EC offers a unique aspect for examining the impact of technology and corresponds to one Perspective, one Quartile and one Cluster. Each EC comes with a unique ID that is constructed by a letters-numbers combination revealing the Quartile (Design: D, Content: C, Compliance: O, Operation: MP), the Cluster (1, 2, …), the Perspective (Cultural Heritage Professional: P, Museum: M, Visitor: V) and the specific place of each EC among its peers (a, b, c, …).

The MUSETECH model is accompanied within this JOCCH issue by an additional electronic resource, the "Companion" which is meant to act as the A to Z guide to the Matrix containing all identified ECs (Evaluation Criteria) presented by Quartile, Cluster and Perspective. The following subsection (5.4) provides only a high-level overview of the Matrix, the ECs and their arrangement under Quartiles, Clusters and Perspectives.

5.4 NAVIGATING THE MATRIX: AN OVERVIEW

The MUSETECH model provides two main components: The Wheel (Figure 2) and the Matrix provided as an additional electronic resource in the "Companion", together with this contribution. The Wheel shows us that museum technology will alter the experience of three symbiotic entities: the Visitor, the Cultural Heritage Professional and the Museum. It also shows us that the life-cycle of any given museum technology has four constituents or phases, named Quartiles: Design, Content, Operation and Compliance. All 121 ECs are included in the Matrix and commented in the "Companion" by Quartile, Cluster and Perspective. For an example of how the Matrix can be navigated, we provide an overview of the Design Quartile (Figure 3) and discuss briefly the Content, Operation and Compliance Quartiles.

Quartile	Clusters	ch Professional	Museum	Visitor
Design	D1 Design & Product Ideation	a Design concept b Integration with exhibition c Integration with other ICT d Balancing physical with digital e Understanding of the fabrication process f In-house technical knowledge	a Innovation, business intelligence b Brand name, uniqueness, originality c Integration with other ICT d Budget e Staff acceptance	a Co-design, front-end evaluation & visitor acceptance
	D2 Experience design and narratives	a Experience added value b Relevance to audience c Tailored content d Attentional Balance e Social Interaction f Before and after the visit support	a Interpretive, educational, learning potential b Personalisation potential c Public outreach and communication d Big data potential	a Engagement b Personalisation c Learning, entertainment, edutainment d Attentional Balance e Affective Impact f Social interaction g Ability to follow usage on other platforms h Sense of belonging to a community
	D3 Interactions, Affordances, Interaction Metaphors	a Affordances b interaction metaphors c Interface design d Clarity of navigation e Follow-up usage on other platforms f Multisensoriality	a Follow-up usage on other platforms b Brand name, uniqueness, originality	a Utility, usability, ease of use b Intuitiveness, learnability, learning curve c Responsiveness d Clarity of navigation e Personalisation f Social interaction g Follow-up usage on other platforms h Multisensoriality
	D4 Aesthetics, Look & Feel, Visceral Qualities	a Look and feel	a Brand name, uniqueness, originality	a Look and feel

Fig. 3. MUSETECH Matrix Detail: The Design Quartile

Design has been defined as "the deliberate shaping of the environment in ways that satisfy individual and societal needs" (Norman 2007). In MUSETECH, the **Design** Quartile includes four Clusters and a total of 49 ECs. Depending on the inherent nature of each cluster, different criteria are identified for the CHP, the Museum and the Visitor. For example, D2: Experience Design and Narratives and D3: Interactions, Affordances, Interaction Metaphors, include a greater number of ECs for the museum visitor perspective capture different aspects for designing captivating digital heritage experiences. D1: Design & Product Ideation Cluster on the other hand, includes a greater number of ECs for the Museum and CHP perspective.

The **Content** Quartile looks into identified challenges in creating, updating, maintaining and fine-tuning content and regroups 18 ECs around two Clusters. C1: Content Creation looks on how the content creation process impacts upon CHPs, Museums and Visitors while C2: Content Maintenance Cluster looks into ECs specific to updating or maintaining content once a digital interactive is up and running.

The **Operation** Quartile includes 34 ECs museums and museum professionals would investigate concerning the start-up, running and maintenance of any given digital museum interactive, device, application or installation. The naming of the four Clusters in this category is indicative of a great number of aspects that should be examined and evaluated. O1: Deployment and setting-up regroups ECs related with the

installation, start-up, fixing or storing of museum technology. O2: Robustness and Maintenance includes ECs such as robustness, responsiveness, stability or level of required maintenance among others. O3: Power and Energy contains all energy-related ECs that should be examined ideally early on in indoor and outdoor heritage sites both for museum and visitor-owned devices. O4: Costs in this Quartile, refers to operational and maintenance costs (complementing the costs EC figuring in the Design Quartile).

The **Compliance** Quartile showcases 20 ECs distributed among three Clusters. MP1: Health, Safety and Accessibility looks at how safe and appropriate is the proposed museum technology while MP2: Logging and Monitoring include ECs that examine from a legal and deontological perspective all issues that might be related with logging in interactions and visitors' data. The last Cluster MP3: Ethics and legal issues includes ECs on relevant issues that often arise in the context of using different types of Museum Technology.

The next section provides three examples of how MUSETECH was used for evaluating museum technology deployed by the meSch EU project.

6 USING THE FRAMEWORK: USE-CASE SCENARIOS

This section discusses three museum technology examples using our evaluation framework. It provides a walkthrough into how the MUSETECH Matrix was used – a posteriori – to reflect upon issues that were raised in evaluation throughout the life-cycle of the project in all Quartiles (Design, Content, Operation and Compliance). Our insights and findings were informed by front-end, formative and summative evaluation, as well as from several hands-on workshops where designers, researchers, engineers and museum professionals contributed. We examine the most important issues by Quartile to provide an example of how we used the Matrix to think about successes and shortcomings of the meSch technology.

6.1 THE INTERACTIVE CASES

6.1.1 Design. "Bespoke designed and built to instigate curiosity via a Twitter conversation" (D1Pa), the meSch showcases (Figure 4a) were co-designed and installed in Museon in 2014 (Petrelli et al. 2014) amidst the permanent museum exhibition (D1Pb). The added value (D2Pa) identified was encouraging visitors to interact via a Twitter conversation with selected museum objects from the reserves of the museum. The use of social media was thought promising for encouraging social interaction (D2Pe) online and onsite (D2Pf). Furthermore, while visitors would be standing in front of the cases, proximity sensors would record how much time in total visitors spent in front of each exhibit. This would result in a competition among the objects; the least successful would be replaced by another exhibit coming from the reserves. The cases were equipped with a digital display, displaying both tweets coming from the exhibit and tweets coming from the visitors in real-time.

Tweeting was the main affordance and interaction metaphor used (D3Pa). This meant that, for a visitor to interact, it was necessary to have a mobile, a Twitter account and the time and interest to make use of those while visiting (D3Pb). As each object had a separate, personal Twitter account, the dialogues around objects and visitors would be available for consulting online and onsite, before, during or after the visit (D3Pf). An interesting aspect was to investigate whether the "popularity" of objects as calculated by the proximity sensors and their display, would affect the behavior of the visitors as well as the actual way they moved and placed themselves in front of the cases (D3Pf).

6.1.2 Content. After the idea was generated (D1Pa), it was important to decide which would be the "competing exhibits". Once the decision for the 20 rolling exhibits (of which 4 were displayed at a time) was made, the content creation process in terms of utility, usability and ease of use, appeared as quite straightforward (C1Pa): the curator had to connect to the account of the exhibit and tweet a question targeting the passing visitor. With the tweets of the visitors appearing in real time, important issues of curating and validating the content in real-time emerged (C1Vb): A curator had to be available around the clock while the installation was functioning. The "competition" metaphor meant that the objects had to be changed on a rolling basis. This activity was undertaken in-house, by the curator in charge.

Fig. 4a-c. From left to right: a. The interactive cases, Museon; b. The Loupe, Allard Pierson Museum; c. "Atlantic Wall: War in the City of Peace", Museon.

6.1.3 Operation. The installation was set in place by the meSch team and the Museon CHPs (O1Pa). The level of customized maintenance required (O2Pc) was manageable yet cumbersome and time-consuming: using special equipment, a curator had to carefully open a case, take out one exhibit, then replace it with another. The front-door staff surveying the visitors and the exhibits eventually grasped the particularities of the display. In hindsight, it would have been beneficial to host a short training session with the museum staff on the floor about how the exhibit actually worked (O1Mc). Visitor-owned devices would be used for interacting (O1Vb) with the exhibit. In terms of robustness and maintenance, the installation was relatively stable with one -daily- exception: closing time coincided with the switch-off of lights and electricity. At the start-up procedure the next open day, a quite laborious process was necessary for the tweet feed to start being displayed again (O2Mb). Brochures were printed out and displayed close to the installation as well as a large poster (see Figure 4a for a poster fragment), explaining the concept and introducing the visitor to the specificities of the display (O5Pa, O5Va).

6.1.4 Compliance. The height of the installation and the proposed "tweet to the exhibit" interaction was suitable for adults, holders of a Twitter account but not for children. This set some constraints on the "accessibility" (MP1Pa) and "appropriateness" (MP1Pb) of the exhibit. Furthermore, real-time communication with the visitors implied a constant monitoring of the visitor-generated content in terms of "appropriateness" (MP1Pb): an "improper" tweet would need to be removed from the display immediately. Logging and monitoring visitors' tweets and movements in front of the showcases was assessed by both the museum staff and the meSch design team as promising in understanding the individual attractive power of each exhibit (MP2a). Using Twitter to encourage the creation of user-generated content gave also an indirect "consent" for sharing or making public the created content, guaranteeing the absence of intellectual property rights issues (MP3Ma).

6.1.5 (*How) Did it work?* A short field-study was carried out onsite to study how this prototype worked in real-life. Although the installation was easy to use (D3Va), it was far from intuitive (D3Vb): after all, there are few, if any, examples of having a dialogue with museum exhibits via Twitter in real-time. The tweeting

function of the exhibit meant that visitors needed to have an active Twitter account (D3Pb). This was problematic as most adult visitors we discussed with mentioned they had a Facebook but not a Twitter account. That made us think that Facebook would have been more advantageous as a platform for dialoguing with the exhibits. Chatting with the gallery front-of-house staff revealed that the actual function of the installation seemed initially a little bit bewildering to them (D1Me). This was a shortcoming as the gallery-floor staff could have been an important ally for the visitor trying to interact with the exhibit (O1Pe). Though the cases had eventually to be removed from the gallery floor, the museum thought of taking the showcases outside the museum, in a theatre or train station, where the attractive and holding power of the installation would be more important and where the actual competition of objects would be funny, interesting and meaningful for the passing visitors.

6.2 THE LOUPE

6.2.1 Design. As its name suggests, the Loupe is a magnifying glass (D1Pa). It is also an AR tangible hiding an iPhone in a wooden encasement (Figure 4b). It uses the technology of AR to present virtual overlays around selected museum exhibits the visitor can interact with (Van der Vaart and Damala 2015; Damala et al. 2016a). How does that change the experience of the visitor in comparison with using a plain smartphone for augmenting the exhibits (D2Pa)? Is it easy and intuitive to use (D3Va)? How do people engage with the objects, the AR display and the content it activates (D2Pd & D2Vd)? When the visitor picks up the Loupe a small tutorial is launched (D2Vc). Then the trail starts: an outline is displayed on the Loupe screen, which the visitor is instructed to match with the right object of a specific display (D3Pc).

6.2.2 Content. The content had to specifically be tailored for the Loupe. Each commented exhibit contained a short narrative about the personalities depicted on the vases and their relationship with Zeus. All selected characters were Zeus's children. A curator worked closely with Merel Van der Vaart, PhD researcher at the University of Amsterdam and meSch project team member, to carefully articulate the narrative around a few chunks of text, "Twitter" style (C1Pa). These would be activated one after the other. As the Loupe's surface is small only a few words could be displayed at a time.

6.2.3 Operation. As this was a small-scale deployment, a test zone was designated inside the museum. After a lot of careful thinking about the appropriate content to test this approach, one specific showcase was selected. An installation had to be set up in the museum (O1Pa & O2Ma) with a mini pedestal and some instructions about how first to interact with the Loupe (O5Pa). The Loupe hung from a hook, waiting to be picked up and activated by the visitor.

6.2.4 Compliance. A medium-scale evaluation study was devised. Consent forms were signed by the visitors-participants, after having gained ethical approval for the study (MP3a). Data would be kept for a period of 5 years (MP3Mc). The test carried out was carefully monitored by two researchers. For a large-scale deployment, we would need to think about safety issues (MP1Pc, MP1Ma) and verify the robustness of the protective case so as to avoid accidents or plan how to manage them in an emergency situation (such as a broken device) (MP1Mb).

6.2.5 (How) Did it work? We were interested in understanding the focus of the visitor's attention, was it the Loupe or the commented object (D2Pd & D2Vd)? We also wanted to learn how easy and intuitive the Loupe was (D3Va). Would the "tangibility" of the Loupe deliver a different experience in comparison with a naked smartphone used pretty much the same way (D3Pf & D3Vh)? We devised an evaluation protocol consisting of observations, a questionnaire and an interview (Van der Vaart & Damala 2015; Damala et al. 2016a). The analysis and interpretation of the data collected showed that although the Loupe was easy to use, it was definitely not intuitive (D3Va). "Diligent" or "experienced" visitors reported being more distracted compared with less experienced visitors (D2Vd). The study also showed that the large majority of the visitors consulted more text than they would have done had the only medium available been the exhibits' text labels. Did the physical form of the Loupe seem to correlate with the experiences? The overwhelming majority of the visitors said they would rather use the Loupe than their own smartphone running the very same AR application. We were also surprised to find out that the experience could easily be shared among visitors visiting in pairs

(D3Vf): sharing the Loupe seemed to stimulate discussions and interaction with other co-visitors, in addition to the objects displayed on the cases and the narrative revealed by the Loupe (Figure 4b).

6.3 ATLANTIC WALL: WAR IN THE CITY OF PEACE

6.3.1 Design. The "Atlantic Wall: War in the City of Peace" exhibition (Figure 4c) narrated the story of the city of The Hague during WW2, when a big part of the city had to be demolished to make space for the Atlantic Wall (Damala et al. 2016b). Hundreds of Dutch civilians were chased away from their houses. It was thought important to provide different perspectives on this period of history of the city (D2Pa). The main idea was to present this period of the city's story from different perspectives (D2Pa), all by encouraging rich, tangible and multisensory visiting and learning experience (D3Pf and D3Vh). Three perspectives were chosen: that of a German soldier, a Dutch citizen and a civil servant who had to collaborate with the occupier. The following mechanism was devised for allowing the visitors to choose their perspective: at the beginning of the exhibition, a showcase displayed 6 original everyday-life WW2 objects. Next to them, 3D-printed replicas of the very same objects could be picked up by the visitor (Figure 4c). Each of the 6 objects would activate one of the three perspectives, in English or Dutch (D3Pb).

6.3.2 Content. The content and narratives used materials found in texts, radio programs or videos of the era. Different stories were created for each one of the three perspectives (D2Pc). Content was created in-house using the meSch authoring tool (C1Pa). This was found easy to use: the main challenge was tailoring the content and the storyline (D2Pc). Using the replicas came with a powerful logging mechanism which allowed the team to get quantitative data about the most and least preferred exhibition sections and audio commentaries (C1Mb).

6.3.3 Operation. Since this was the first time that the museum was using at such a wide scale tangible interactives, an important question was how this would work at a large scale. Would the replicas disappear or break (O3Pa)? Would the visitors actually use the replicas (O4Va)? It was thought important to make the museum exhibition accessible for visiting without having to use the replicas. In this sense, the replicas would only activate content additional to that already displayed. The replicas turned out to be quite robust (O2Va). However, when the exhibition opened, it was obvious that many visitors bypassed the "check-in" station which contained the original objects and the replicas. A few days later, additional material (OP5a) was set in place close to the check-in station to help facilitate with understanding how to use the replicas. The staff (including museum volunteers) helped with replacing and arranging misplaced replicas. They also often assisted in giving advice to the visitors (O1Mc).

6.3.4 Compliance. The replicas proved to be popular with both children and adults (M1Pa & M1Pb). As all replicas were made from sturdy materials, there was no risk of being broken (M1Pa). At the end of the visit, the visitor could use the replica to get a personal post-card displaying these sections of the exhibition where they had spent more time (MP2a & MP2Va). This gave the museum valuable data from the approximately 20,000 visitors who visited the exhibition.

6.3.5 (How) Did it work? A large-scale evaluation study was devised, gaining ethics approval from the universities whose staff participated in the field-study and the audience research (MP3Pa, MP3Pb). For this study, we used video recordings, questionnaires, observations as well as interviews conducted with consenting visitor-study participants approximately six months after the visit. As also discovered in the Loupe study, using the replicas was easy once the interaction metaphor was grasped (D3Pb). However, it was not considered as equally intuitive (D3Vb). We also met visitors who happened to carry out their second or third visit. All of those visitors came back to revisit the exhibition using a different perspective. Other visitors chose to use more than one replica simultaneously to get more than one perspective (D2Pb, D2Vb). One of the features used less than anticipated was printing out a postcard souvenir upon returning the replica to a "check-out" station. Though additional signposting was set in place (O5Pa), this feature was missed by several visitors who had difficulties grasping the mechanism. The replicas were appreciated by the visitors, while they seemed perfectly appropriate for all ages (Figure 4c).

7 DISCUSSION

MUSETECH offers two main components: The MUSETECH Wheel and the Matrix. The Wheel is there to remind us that the introduction of any museum technology will have an impact on how heritage is experienced by the museum visitor, CHPs and the museum as an institution. The Wheel has four main constituents: Design, Content, Operation and Compliance (Figure 2) which we called Quartiles. A total of 121 Evaluation Criteria were clustered in groups under one or more of the Quartiles. Some overlaps are present: even though the museum as institution is run by CHPs, we deemed it essential to match criteria against the museum professional as separate entity. The CHP experience from using technology is usually not sufficiently recognized in the literature which mainly focuses around questions of "digital literacy". However, the CHP is the main driving force behind many technology undertakings.

Modelling the museum and the CHP as separate entities allowed for breadth and depth in identifying evaluation criteria. The downside is that this approach comes also with some overlaps. Differentiating what needs to be accounted for, assessed and evaluated for the museum versus the CHP is sometimes hard. What is the role and responsibility of the CHP and the Museum regarding logging data? The difference is almost imperceptible yet present. This is reflected in the different criteria on logging and analysing data, identified under more than one constituent and perspective (C1Mb, MP2Ma, D2Md). These point to different aspects in logging and recording visitor data so as to enhance the visitor experience (D2Md) and help the museum understand its audiences. Similar nuances also exist for a number of criteria (e.g. continuity of content usage, personalisation, and attentional balance).

Another issue to be flagged is that not all 121 criteria are valid for all types of museum technology: a museum website is not expected to be evaluated the same way as the performance of a museum on its social media platforms. However, we hope that the majority of pertinent, relevant and important to ask questions for introducing museum technology are included in the Matrix, whether this involves a 3D-printed souvenir, a tangible, a tabletop, an audio-guide or "smart" ticketing systems.

All criteria are there to be used as a guide for recording, benchmarking, and evaluating the multifaceted impact from the use of museum technology. The Matrix has different entry points, whether this is the perspective (CHP, Museum and Visitor) or the four Quartiles (Design, Content, Operation and Compliance). This modelling provides some hints as to how the Matrix could be navigated. A further challenge is that the constituents as well as the perspectives cannot be arranged or articulated in a sequential order. Criteria listed under the Compliance quartile will need to be taken into consideration for Design. Reflecting on Content might precede the Design constituent in terms of start-to-finish order. This approach is quite different to the linear approach of evaluating digital museum technology identified in a prescient paper dating back to 1998 (Economou 1998): "(a) research on the content of the application, (b) collection of the material, (c) multimedia design and programming, (d) formative evaluation, (e) integration in a museum exhibition, (f) summative evaluation of the program's effectiveness, (g) study of the long-term effect on visitors and (h) impact on museum staff." As in reality, these steps may have to be taken various times iteratively, we believe that the multi-entry particularity of the MUSETECH model is also one of its main strengths.

All 121 criteria contribute towards understanding the "what" of evaluation and could be used before, during or after an intervention has taken place. The framework does not tell us the "how". This comes as no surprise: one of the few things specialists do agree upon is that there exists no magic formula or recipe for evaluating museum technology (Economou 2016; Diamond et al. 2016). The "how" also happens to be influenced by diverse disciplines: human-computer interaction, data science, ethnography, ethnomethodology, sociology, anthropology, cognitive science, marketing or psychology. Then there are also different evaluation methodologies, qualitative, quantitative or mixed-methods. The "how" might also involve things as diverse as discussing with the museum staff on the ground what went wrong, brainstorming with all museum staff, logging in data, interviewing visitors, observing their web behaviour or opting for co-creation and co-curation activities with the visitor. The literature is rich in resources talking about how to plan for evaluation with regards to the "when" (front-end, formative or summative) and the "how".

As a rule of thumb concerning MUSETECH, we propose using the Matrix for identifying a maximum of four to five key questions related to a museum technology program. Once these have been clarified, the

Matrix can be revisited for identifying new criteria that need to be considered. In order to demonstrate how something like that could work, we provided three examples of museum technology brought to life by the meSch project. These use-cases prove how the Matrix can assist in reflecting about possible impacts of technology for the CHP, the museum and the visitor. A word of caution is needed: as the Matrix was developed in parallel with the use-cases described, further, large-scale validation is needed to collaboratively and creatively create new concrete knowledge about how the Matrix can be used at the very initial stages which precede the introduction of a specific museum technology. This might allow to establish emerging sequential patterns correlating the "what" with the "when". From there, the table could be enriched with existing literature and resources for all Quartiles, Clusters and ECs (Evaluation Criteria). The coordinates system devised for uniquely identifying each criterion could play an important role towards this direction.

8 CONCLUSIONS

The multifaceted use and potential of museum technology is clearly beyond any doubt. The MUSETECH model came as a response to the pressing need of devising evaluation, assessment and benchmarking mechanisms for different types of museum technology.

We advocated that in order to better comprehend this complex challenge, it is important to take under consideration the views and perspectives of the three identified symbiotic entities: the museum, the visitor and the Cultural Heritage Professional. To the best of our knowledge, this is also the first time that all of these three entities and their everyday living and working experiences from using technology are formally visited, formalized and accounted for within the same model.

Although navigating within Quartiles, Clusters and all 121 criteria is no small feat, we hope that this is counterbalanced by the model's versatility and expandability and that we have laid down the foundations for a framework which can assist in approaching the impact of museum technology, in terms of risks and challenges as well as in terms of planning for and managing change. We also hope that we have provided some solid ground in terms of modelling how one can talk and think about museum technology. This is a "living" framework that can be extended as new types of technology raise new questions about their use and evaluation.

Testing the Wheel and the Matrix in new contexts could result in debates which will allow further developing and refining of the model. Further ahead, the framework could be enriched by adding to it the views and perspectives of governmental bodies, policy makers, technology companies and cultural creative producers, sponsors and other patrons. A future direction may also be to consider what can be deleted as not serving useful functions.

Until then, we hope that the MUSETECH will reinstate our confidence in considering the technology as a muse rather than a calamity. For that, we need to take a step back and look through technology rather than stare at it.

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