

CRAFTING THE NEXT GENERATION OF WEB-BASED LEARNING TOOLS FOR MANUSCRIPT ARTEFACTS IN THE TIME OF THE COVID-19 PANDEMIC. A FOCUS ON SCIENCE, TECHNOLOGY, AND ENGINEERING CODICES, WORLD MAPS, AND ARCHIVAL DOCUMENTS IN EXHIBITION SETTINGS

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Abstract

This paper starts with a review of the secondary literature published in English about the strengths and weaknesses of the web-based learning tools available in museum systems as brought forward by the outbreak of the COVID-19 pandemic in 2020. Next, this review contextualises the solutions designed and developed within the Engineering-Historical-Memory online interactive system to fully access permanent and temporary exhibitions and discover the knowledge embedded in manuscript artefacts via the visitor's smart device or institutional interactive screens. With these solutions, the original artefacts, or their physical and digital replicas, become gateways to online interactive applications. These applications provide high-definition 2D and 3D reproductions of the artefacts and make them explorable by free navigation or via graphs and geospatial views with an automatic real-time update for relevant scholarly publications, images, and videos.

Keywords

Digital Humanities, Science, Technology, and Engineering Manuscripts, Archival Documents, World Maps, Engineering Historical Memory, 2D and 3D Web-based Reproductions, Web-based Learning Tools for Exhibition Settings.

1. Introduction

In the first two decades of the twenty-first century, museums have more and more moved from object-based curatorial practices towards visitor-centred experiences and post-critical museologies in support of the acquisition of knowledge (Reeve & Woollard, 2006; Murawska-Muthesius & Piotrowsky, 2016; Falk, 2016). This paper—which can be construed as an initial review instrumental to research contextualisation—examines the impact that the coronavirus disease 2019 (COVID-19) pandemic had on the learning opportunities provided by the study (i.e., the devotion of time and attention to aggregate relevant already existing and consolidated knowledge), involvement (practical observation and contact with facts and events), and being taught (instruction, training, and education) in both physical museographic spaces and online environments in 2020.

The authors reviewed publications in English available online through Google Scholar, JSTOR, Taylor & Francis, and Scopus Elsevier, released by

the end of January 2021. The review paid particular attention to the evolution of web-based learning tools in museum systems during the 2020 lockdowns. Through this lens, this paper has considered the reports issued by the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2020), the International Council of Museums (ICOM, 2020), and the Network of European Museum Organisation (NEMO, 2020a; 2020b; 2021), along with papers on specific countries, such as UK and USA, seen as best-studied countries (Samaroudi, Echavarria, & Perry, 2020; Ciecko, 2020), Italy because of the high concentration of pre-COVID-19 most visited museums (Agostino, Arnaboldi, & Lampis, 2020), and Singapore in reason of its novel and innovative museum system (Tan, 2020).

This scholarship served to contextualise the research on innovative solutions for free online access to knowledge embedded in manuscript artefacts undertaken by the Engineering Historical Memory (EHM) team between 2019 and 2021.

The focus on manuscripts is not only because they constitute a particular cultural-heritage

category preserved in libraries, archives, and museums worldwide as highlighted by the [UNESCO Memory of the World Programme](#), but also because, in exhibition settings, they present additional critical challenges if compared to other artefacts. Indeed, in physical exhibition spaces,

1. codices are open on one double-page only and cannot be browsed,
2. large-size and highly-detailed manuscripts such as world maps are kept too far from the visitor's eye to allow the reading of the pictorial and written elements,
3. texts are often unreadable for most of the visitors because of the handwriting and the language,
4. critical editions, commentaries, translations of the texts and related secondary literature are not immediately available.

Today, the first two issues have been addressed. They are somehow solved in the digital space since most of the leading cultural institutions have a digital library of high-resolution 2D reproductions that can be accessed online. However, these digital reproductions are generally not available in exhibition and reading-room settings. And, even when available, they are usually complemented only by essential catalographic captions that do not take full advantage of the internet's opportunities in addressing the points mentioned above as (3) and (4) in real-time. Today, technology allows knowledge aggregations of existing scholarship accumulated on the artefacts over time and across different languages. This knowledge can be dispensed according to the user's specific interest and expertise while experiencing an original manuscript artefact or its replica in an exhibition setting or the reading room of an archive or a library or immersed into a digital space.

In this context, the present paper aims to showcase how the EHM research team crafted web-based tools as solutions to existing learning challenges in permanent and temporary exhibition settings: (1) digital recomposition and restoration of the photographic survey of original manuscripts with customary deep-zoom visualisation tools to browse 2D and 3D reproductions; (2) interactive accessibility to the information available in traditional scholarship (e.g., editions, commentaries, translations); (3) free and direct exploration or access to information via graphs and geospatial views; (4) real-time and automatic

update for related scholarly publications, images, and videos; (5) possibility to access and store knowledge in front of original artefacts or replicas (including projection mapping, VR, and AR) in any exhibition setting via BYOD (Bring Your Own Device) or interactive screens if Wi-Fi is not available.

EHM started in 2007 (Nanetti, September 2020). Since then, EHM is an ongoing research project that welcomes international and multidisciplinary collaboration to design and test interactive applications for the virtual (re) organisation and delivery of historical knowledge in the digital age. The EHM research team studies and practises "by what means" traditional historical scholarship can supply machine-understandable information. The aim is to empower historical sciences with artificial intelligence and machine learning, enabling all users to read primary historical sources according to different knowledge and expertise levels interactively. In the history domain, EHM makes a cross-disciplinary use of established research processes, such as mapping as understood in mathematics and linguistics (i.e., an operation that associates each element of a given set, the domain, with one or more items of a second set, the range) and parsing as understood in computing (i.e., analyse narratives into logical syntactic components) to kick-off the exploration of primary historical sources. Using these operations of mapping and parsing for individual primary historical sources, EHM associates each element of given sets of information provided by the domain of the traditional disciplines (e.g., history, art history, philology, palaeography, diplomatics, codicology, archaeology, epigraphy, sigillography) with one or more elements of the range of machine-readable content management systems (e.g., spreadsheets, computational notebooks).

The level of accuracy of this preliminary human activity is directly proportional to that of the aggregations generated and visualised by the EHM algorithms from different sets of similar written or depicted elements in the EHM database (e.g., geographical names, people's names, goods, ships, governments, events, architectures, drawings) and potentially relevant publications, images, and videos retrieved in online repositories in real-time. To understand and emphasise the unity of EHM as an interactive system in the approach to historical information, the rhetorical and conceptual linking of "mapping and

visualisation” and “search and visualisation” should be hendiads. Thus, the term “mapping” is understood, in its primary meaning, as the localisation and description of elements, facts, or phenomena related to a circumscribed area, historically understood at the intersection of precise space and time coordinates. The aim is to provide and test an example of an innovative epistemological process to distil historical data visually. The “visualisation” process is seen not as a reductive representation to epitomise and/or illustrate written narratives but as an investigative tool that the historian (especially one who intends to enter fully into the digital era) can use for discovering and organising new relationships between objects, in a new historical landscape where past, present, and future can merge in a democratised whole (refer to Altman, 2008; and Bolick, 2006).

This paper is structured in eight sections (including this *Introduction* and the *Conclusions*). Section 2 presents a review of the publications in English about the online response given from museums to the COVID-19 world pandemic. Section 3 introduces UK and USA museums as best-studied experiences of the opening of collections to an online audience during the pandemic. Section 4 investigates the relationship between museums and social media in Italy as the highest concentration of most visited museums before the pandemic. Section 5 analyses a few remarkable examples of web-based learning tools developed for manuscript artefacts before the pandemic. Section 6 presents examples of web-based learning tools developed by EHM for world maps, archival documents, and science, technology, & engineering codices. The paper ends with the acknowledgements of research collaborations and bibliographical references.

2. Museums and the COVID-19 World Pandemic

The UNESCO (2020) shared information on how the COVID-19 pandemic in member states impacted the museum sector¹. The examples are skewed towards the Americas and Europe, with the United States contributing over 33,000

museums and Europe with over 28,000 museums on the statistics. Meanwhile, the Chinese museums' statistics barely made it past 1,000, most of which have yet to be validated by China.

In this period, most of these museums have experienced new ways to reach their public online through social media applications, virtual tours, interviews with curators and directors, webinars, etc. According to UNESCO (2020, 15-16), museum institutions have utilised their digitised collections to move online their pre-planned events since the lockdowns. Also, several past exhibitions and even games were digitised and posted online. Recorded seminars, concerts, curatorial talks were made accessible through online digital platforms such as YouTube or SoundCloud, podcasts, virtual exhibitions and 360-degree tours to showcase their collections. The addition of new social media material assisted in the partial transformation of several museums into diversified digital media. Curators and management teams became more involved in digital initiatives to bring their projects online and create communities of online users.

Three new modes of intervention are on the horizon, all of which seem to diverge from the conventional pre-pandemic initiatives. The first area of action is museum programs and collections, which would include detailed mediation. For example, museums have tried to utilise empty spaces and provide unusual exhibition tours, such as the one led by a robot (UNESCO, 2020, 17). In addition, the notion of joining in a “cocktail with the curators” (Frick Series, New York), “associating a work with a song” (Valence Museum, France), or showing the museum's collections using their reproductions in a computer game (the Angermuseum, Germany with Animal Crossing) have all been introduced to engage the visitors.

Several museums took advantage of this period to display “the other side of the coin,” which means reserves or other “invisible” museum collections (UNESCO, 2020, 18). Community managers' strategies for appealing to viewers by participatory acts have been widely used. Especially in Western Europe, many games

¹ The survey was limited to the museums that are in UN member states. It began on 16 April 2020, with the latest information returned being incorporated up to 20 May 2020. Four critical sets of information were investigated: the number of museums in each member state; the number of museums that closed during the COVID-19 crisis; the online activities (virtual tours, exhibitions of permanent collections,

training, educational programmes, children's games, etc.) proposed by museums; and the measures taken by each member state along with the actions to be implemented in the medium/long term in a context of lockdown and the assistance that the UNESCO could provide to museums in those critical circumstances.

featuring parents and children have been set up to assist parents looking to occupy their children with enjoyable and engaging events: puzzles, educational games, children's books, quizzes, video games, and colouring activities. The *Musée des Plans-Reliefs* (Paris), for example, created a downloadable "memory" game. The "#GettyMuseumChallenge" (Getty Museum, Los Angeles), which was influenced by "Between Art and Quarantine" (Rijksmuseum, Amsterdam), promoted foreign involvement and was widely publicised in conventional media. At Montevideo's *Museo de Arte Precolombino e Indígena*, staff avatars offered games for girls. COVID-19-related selection practices have since been implemented by other museums (UNESCO, 2020, 19).

Worldwide, several museums, museum associations and programs (e.g., *Ibermuseos*, ICOM, Ontario Museums Association, Association of Children's Museums, Virginia Association of Museums, Association of Academic Museums and Galleries) quickly launched web conferences in the form of webinars or meetings and talks through Zoom, Skype, and Google Hangouts in a more strictly professional and scientific manner. Thus, although the current work addresses the COVID-19 crisis, it seems plausible that it will continue to be pursued in the future (UNESCO, 2020, 20).

In Europe, four out of five museums have expanded their streaming offerings to reach their audiences, with personnel taking on additional responsibilities to deal with the situation. About half of those who responded said that their museum already has one or more innovative online offerings. Over the monitoring period, two out of five museums announced a rise in web visitors varying from 10 to 150 per cent. However, there is no improvement in production without additional input. According to the survey, museums willing to adjust personnel roles and/or incorporate funding could expand their interactive offerings and saw a spike in online visitors.

People visit museums for educational and collection-related interests. Apart from social media contents, museums indicated that instructional and collections-related materials, such as videos and films, were the most common with online visitors. This study found that online museums are valuable additions and complement to traditional museums but that a reliable method to evaluate online visits is lacking (NEMO, 2020, 3). Considering that the "current standard" might affect almost every museum-practice area in the

future, an option under discussion is that identifying features from existing experiences could help transform museums into flexible and receptive representatives of their societies. Thus, this evolving environment necessitates updated performance metrics and, consequentially, investments (NEMO, 2020, 4).

The Network of European Museum Organizations calls for all stakeholders to recognise "that digital cultural heritage and digital interaction" have recently shown their importance by bringing citizens together, promoting imagination, exchanging interactions, and providing a virtual forum for people to collaborate on ideas. In the future, this recognition can be turned into developments in digital networks and infrastructures. Considering interactive museum programs, events, and digital audience participation as performance indicators in evaluation frameworks has proved to be a significant "best practice" (NEMO, 2020, 6).

An agreed-upon metric for a better understanding of internet visits will help with benchmarking, decision-making, and resource utilisation. Otherwise, museums might fall "behind in the digital literacy transformation". In the past, museums have conducted guest study and analysis on exhibits and instructional activities onsite. Now, they should be allowed to acquire the expertise and tools to make it happen in the digital while investing in the things that make museums unique: their exhibits and diverse materials. In addition, the digital future of museums aims to provide entertaining and innovative digital offerings. For these activities, museums seek funding "to compete with other digital services and provide" cutting-edge cultural experiences online (NEMO, 2020, 23).

3. *UK, USA, and Singapore museums as best-studied experiences of opening collections to an online audience during the pandemic*

As part of the above-mentioned broader goals, heritage organisations issued further recommendations on using internet resources to assist communities throughout the pandemic (Ciecko, 2020; ICOM, 2020; NEMO, 2020a). Access to online collections through digital copies, exhibits, and other projects are among them. For example, a piece of recent news, dated 28 March 2021, showcases the Louvre Museum putting its entire art collection, consisting of more than

480,000 pieces, free and open access online (Elassar, 2021).

In general, the advice to maintain contact with audiences through digital resources and channels, such as blog information, social networking material, images, podcasts, and more, appears to have been well received by museums. Curators created audio tours of exhibitions, conversations about the exhibits, and review of exciting subjects through widely used social networking sites, such as Pinterest, Twitter, Facebook, Instagram Live, YouTube Live, blog posts, and podcasts, where competitions and quizzes utilise hashtags to inspire people to share their stories on a range of collection-related subjects.

Even though most web pages provide text and picture components only, the survey included other media such as video (including live video streams), audio, immersive games and events, 3D object explorations, 360-degree virtual tours, and interactive panoramas/VR/AR-style interactions (Agostino et al., 2020, 338-339). In addition, free domain discovery, supervised exploration, collection-related tools, 3D collection, image database/resources, and gathering material are examples of the so-called collection-style digital offerings (Agostino et al., 2020, 340). The latter was especially intriguing because, during the lockdown, several remembrance organisations were systematically collecting digital material or artefacts from the public.

Interactive trips—in the form of 360-degree encounters, VR/AR interactions, or "audio tours"—were less commonly offered, accounting for just 2 per cent of the USA and 3% of the UK offerings, rendering them the least popular category of digital service in both countries. Even though people couldn't physically access memory institutions, there were very few interactive tours accessible. According to one survey, only twenty 360-degree gallery tours were registered, accounting for a minimal percentage of the total offerings (Agostino et al., 2020, 352).

However, collection and communication-related digital offerings were the most common in the UK and the USA. Both countries accounted for 71% of the gross offers. Selection style digital offerings accounted for 29 per cent of overall digital offerings in the UK, while Contact type accounted for 42 per cent. The USA National Gallery of Art, like other museums, has stepped away from a public-centric model to a more online approach, according to Kaywin Feldman (2020, 2).

The gallery provides interactive tours of museums and exhibits and family and educational material, as well as video videos, performances, and seminars, through their website and social networking channels (Agostino et al., 2020, 343).

Based on the background provided by technical association polls, the biggest hurdle was a shortage of resources and facilities to develop such experiences. Few museums have previously experimented with interactive tours by partnerships with Google Arts & Culture Street View panoramas (Google Arts & Culture, 2020; (Samaroudi et al., 2020, 337)) or in-house productions (Birmingham Museum and Art Gallery; Frank Lloyd Wright Foundation). Exhibition tours, such as the last-minute video with the director of Michelangelo's exhibition at the Getty Center, were filmed just before the museum's closing (*The Getty*, 2020); live activities to travel across indoor-outdoor spaces were also given as interactive visits. History/Historic Houses or Places seem to have a disproportionately large number of learning-related experiences and material in either scenario. Art organisations and Art and History museums, which also gave the most significant number of interactive tours and solicited support from commercial sources, provided most home events. Museums and other cultural institutions related to the arts and art history, among others, offered well-being activities as part of their multimedia offerings.

Interactivity was known for providing imaginative experiences and instructional content in the form of games and activities. Digital tours in 360 degrees were mainly available for gallery tours. Although there are no universally accepted tools or benchmarks for measuring digital interaction, some answers can be found in the relationships between viewer and company and between host and customer (Feldman, 2020, 6).

Lastly, 3D items and material for supervised explorations and collection-related materials are made available as part of online collections. However, their availability accounted for one per cent of all digital services, rendering them the least popular form of content available. The most common website for providing 3D collections of museum artefacts was Sketchfab. Among the museums that offer access to this web service in the UK, the survey listed the British Museum and the Science Museum Group (*Science Museum Group*, 2020; *The British Museum*, 2020). Other illustrations include a game focused on 3D models

for studying how scientists interpret various characteristics of animal skulls to determine their sources (*Virtual Vizcaya*, 2020) and immersive visualisation of terrestrial laser scanner data for discovering spaces that cannot be physically reached (Agostino et al. 2020, 353).

In Singapore, Alvin Tan states that more than 58 per cent of respondents expressed interest in the growth of multimedia exhibits, interactive tours, and online learning programs in terms of digital needs. Museums are now eager to showcase their collections digitally and to use hashtags to improve their online exposure. However, respondents listed a shortage of resources and specialist skillsets and human capital constraints as significant obstacles in developing and implementing these digital initiatives (Tan, 2020).

In Singapore, respondents ranked interactivity as the most critical component of capability growth. For example, one such project was the interactive exhibition *An Old New World: Digital Edition*, which explored Singapore's mythological and historical origins. As part of a broader effort to encourage audiences to explore the roots.gov.sg platform, online treasure hunts have also added to the national collection's website.

4. *Museums in Italy in 2020. A focus on social media in the country with the pre-pandemic highest concentration of most visited museums*

According to Agostino et al. (2020, 363), 45 per cent of the global population has a social networking account, with 42 per cent of Italians utilising social media. Since 2014, when Dario Franceschini became the Italian Minister of Culture, digital creativity and technology have been a constant part of museum management in Italy. The goals were to create a national museum network (*Sistema Museale Nazionale*) to highlight the cultural resources of approximately 5,000 museums and display and encourage them and their collections to move into the digital. In 2018, Franceschini initiated a project that included real-time tracking of state museum operation on social media and the public's reaction, which had internet feedback to see how the public appreciated them.

Since March 2020, when Italy was put under lockdown and all museums were forced to close, online traffic on all social networking sites more than doubled. Museums used to post 25 times a month on Facebook on average before March, but that number jumped to 40 afterwards. On Twitter,

the previous 32 monthly posts increased to 60, and on Instagram, they more than multiplied, from 15 to 33 monthly posts per museum (Agostino et al., 2020, 364).

Museums also expanded their web presence while changing the content they submitted across these platforms. Social networking has developed from virtual contact platforms to information dissemination tools. Some museums, for example, are also utilising Facebook to post details regarding a work of art and expose previously unseen facets of it. Other museums have paid for specialist interviews or organised tours led by the head of the institution. Others have taken a more 'pleasant' route, hosting interactive treasure hunts across the museum's collections or hosting quizzes (Agostino et al., 2020, 365-366).

The Italian Ministry of Culture has also enhanced cultural engagement using interactive culture-related flash mobs and inviting museums. The first flash mob, dubbed 'ArtYouReady,' was held on Sunday, 29 March 2020, and participants were asked to share pictures of their favourite cultural sites. Other related interactive flash mobs, such as 'Journey Across Italy' (*Viaggio-in-Italia*)—where people were invited to post photos of the Italian countryside with summer on the horizon—were accompanied by 'ArtYouReady' as a daily Sunday feature. The most considerable distinction between an in-person experience and these online programs is that the latter takes far less time. They usually last just a few minutes, two or three, to read a post about a work of art and no more than 10–15 minutes for an interview or virtual tour. In addition, users are "encouraged to meet up every day at the same time" to link to the museum's social platform for a total dose of culture at each meeting (Agostino et al., 2020, 367).

The various forms of content available (e.g., interviews, exploring an artwork, quizzes, simulated visits) set in motion multiple methods for communicating with the public. The first is an interactive technique through which the museum provides information to the visitor. Asynchronous participation is the second way the person is sent details or content but is not expected to participate or react to social media. This category includes treasure hunts and online flash mobs. Finally, synchronous contact, through which the museum and the visitor collaborate in real-time, is the third solution. The partnership is two-way in this situation, but it is still simultaneous, unlike the previous case. Also, educational activities with

real-time contact between the museum and students/children and visits with Museum Friends are included in this category but are the least common (Agostino et al., 2020, 368).

Virtual visitors have honed their ability to choose the most appropriate cultural offerings that better complement their interests. Looking forward, we'll almost certainly be dealing with a human setting, with growing hybrid usage of web-based applications along with the physical world (Ballina, Valdes, & Del Valle, 2019). On the one side, museums gained many new supporters, showing that the public is becoming more interested in museum projects. The people, on the other side, were limited in their involvement and did not expand in the same way as the followers. In other words, a museum that is more involved online (as demonstrated by the rising trend in followers) is more likely to draw visitors. At the same time, interactivity is minimal (Agostino et al., 2020, 369). Visits are no longer one, two, or three hours long but last a few minutes and meet a particular schedule. The interest may include, for example, an emphasis on an object from the museum's holdings related to "what occurred on this day."

As a result, other hypotheses on how museums could provide customised content to visitors in the future have emerged (whether online or onsite). For example, artificial intelligence programs that, through profiling particular individuals, will come up with a museum itinerary or collection of artworks that are more likely to mirror their tastes may be a significant change of pace for museums (Agostino et al., 2020, 370). However, what seems to be missing are tools to make the exhibition setting (either physical, or online, or hybrid) become an open gateway to the treasure of human experiences embodied in the artefacts and supply this wealth of knowledge according to the different interests and attitudes of each user.

5. Manuscript Artefacts in Web-Based Exhibition Settings. A Few Significant Examples.

In the context of the experiences surveyed here above in Sections 2-4, manuscript artefacts constitute an exceptional example to understand what can come next in the web-based learning experiences offered to museum audiences online. The main reason is that manuscripts present

additional challenges in terms of communication compared to other cultural-heritage artefacts. Thus, once methods are found to share manuscripts content with a wide range of audiences and interests, similar solutions can also apply to other museum artefacts. As mentioned above in the *Introduction*, some challenges have been addressed before the COVID-19 pandemic between 2018 and 2019.

In 2018, Bill Gates launched a digital project called *Codescope* for Leonardo da Vinci's notebook, known as Codex Leicester, that he had purchased at auction at Christie's in 1994 for US\$30.8 million. The *Codescope* is a touch-screen interactive application for exploring all the thirty-six digitised pages of the codex. The typical Da Vinci's mirror writing is flipped, the text translated into English, and some animations of the drawings are featured. At the time, the idea was that the codex and the touch screen would travel together onto various museums across Europe as part of the five-hundred anniversary of Leonardo da Vinci's death in 2019. Due to artefact preservation issues, the codex is sealed behind protective glass. The *Codescope*, as a digital kiosk, allows some kind of "physical" interaction or perusal of the notebook (Gates, 2018).

In 2019, the *Codex Atlanticus*, which features Leonardo da Vinci's most extensive collection of original drawings (1,119 pages), was made available online by the *Biblioteca Ambrosiana* with more sophisticated learning tools to inspect drawings and texts in detail and search them by themes such as "Geometry, Algebra, Physics, Natural Sciences, Tools, Machines, Architecture, Applied Arts, and Human Sciences"² (*Codex Atlanticus*, 2020).

On the upper section of the web page, two different bars allow topics to be sorted out per page or year by a dragging feature. The method of reading the codex is broken into ten steps. Firstly, the page graphic and general overview show how the page is sectioned into proportions related to a particular subject with five different colours to differentiate the topics. Indicators correspond to a page number that ranges from 1 to 1,119 and the year of writing (between 1478 to 1519). A rhombus joined onto a solid line represents the page number indicator and is positioned horizontally along the width of the graph

² In total, Geometry and Algebra make up 1,141 entries, Physics and Natural Sciences score 1,004. Tools and

Machines make up 904. Architecture and Applied Arts are 496 and Human Sciences 429.

corresponding to the appropriate page number. A circle with a dashed line placed along the width of the rectangle represents the year of writing. The subjects and topics section allows users to select specific subjects that interest them and filter through the relevant pages in the overview. The bars “represent each subject and are proportional to the frequency of the topics on each page, visually and displaying the numerical results of the selection, Below the subjects, a list of topics will be highlighted, and each entry may be chosen to access pages of the General Summary that pertain to the particular issue. Users could also search the web through a numerical sequence where a graph indicates the page number starting from 1 to 1,119. The number of subjects on each section is proportionately reflected on each page. Certain sections in the General Summary appear when the user drags and picks individual parts of the graph. If users sort the page out by chronological order, a graph indicates the number of pages produced each year from 1478 to 1519. In the General Overview, dragging and clicking a certain span would only display pages created within that time frame. Users may still opt to use the 237 pages for which no year of writing has been allocated. Selecting active pages only displays the effects of the current list. Selecting “all pages” greys out all pages not included in the selection yet encourages users to look for macro-evidence on all 1,119 pages. A survey tool is available by scrolling through the individual pages with the cursor, with markers relating to the page number and date of writing. The effects of the choices taken in the General Review are shown in the upper segment. It illustrates the current section and displays samples of the pages used in the selection. A dropdown arrow on the left displays the currently selected areas, and you can swipe sideways across the excerpts and access pages of significance. The indicators may also be used to move to the previous or next tab. (*Codex Atlanticus*, 2020).

Virtual exhibitions are also vital in the development of web-based learning tools. For example, the *Museo Galileo* (Institute and Museum of the History of Science, Florence, Italy) offers virtual exhibitions and currently runs twelve virtual shows (IMHS, 2021). The 2016 virtual exhibition regarding Amerigo Vespucci and Martin Waldseemüller’s map is fascinating for the interactive exploration of the map and the discovery tools (IMHS, 2016). The interactive map features twelve open menu tabs that are expansive

and provides enough contextual knowledge or information to its users. The virtual map starts with giving the historical context, which discusses classical literature on cosmography, literary and geographic discoveries, humanism and cartography, Ptolemy’s theory on geography and its Latin translations, mentions of Henricus Martellus Germanus and Matthias Ringmann in a short-format video, followed by a timeline from 1490 to 1516. The map is sectioned into twelve different sheets stitched together through digital processes (IMHS, 2016).

These online learning tools address the critical challenges of manuscript artefacts in exhibition settings as mentioned in the *Introduction* only partially because the link between the manuscript artefact, the knowledge embedded in the work, critical editions, and secondary literature cannot be updated in real-time and automatically. These products are static and mimic the book in an online environment without leveraging the dynamic potential of the internet.

Since 2007, the EHM research team pioneers and tests new sets of methods to explore what can be created beyond the book for the online publication of primary historical sources. Within EHM, the main innovation is that the user can interactively explore the document’s digital images along with their critical editions and stay tuned with relevant secondary literature, images, and videos in real-time and automatically.

6. Examples of EHM Web-based Learning Tools for Science, Technology, and Engineering Codices, World Maps, and Archival Documents

The EHM engineering process starts with the aggregation of traditionally acquired scholarship (e.g., books and papers) organised into two main streams: texts and images. Information is parsed and transferred into machine-understandable formats using Google Spreadsheet as a content management system and data storage solution. This system has several concurrent advantages: powerful, popular, secure, robust, customisable, easy backup, and, finally, the similarity with MySQL database in table-like construction.

Each item is identified using a relevant Wikipedia page whenever available. Based on this identification, EHM picks keywords and filters to aggregate knowledge from leading online repositories about any item selected by the user in the online application in real-time. Some of the resources are searched through their API

(application programming interface), which is either public (e.g., Europeana, Gallica, YouTube, Vimeo, Google Images, Bing Images) or shared upon research collaboration agreements (e.g., Taylor & Francis, Scopus-Elsevier). Other online repositories do not have the policy to share their APIs for federated searches publicly. In these cases, the user is prompted to link to the official websites in separate tabs, one by one; an automated query consistent with the selected item is automatically filled to facilitate the search. Online repositories without API are not included in the EHM search (e.g., SmartHistory). With most resources, search APIs work by looking for input keywords in the digital documents accessible online (title, author, abstract, full text). Taylor & Francis also provides a cutting-edge service, which allows searching by “concepts” related to the set keywords. In EHM, the search results are visualised under four categories as follows.

- Scholarly publications from Europeana, Gallica, Taylor & Francis, Scopus-Elsevier, via API.
- Images from Google Images, Bing Images, via API.
- Videos from YouTube, Vimeo, I-Media Cities, via API.
- Guided search in other relevant resources that do not share their API publicly (e.g., GettyImages, Google Scholar, JSTOR, China National Knowledge Infrastructure, Wanfang Data, Pelagios, Blackwell).

These tools can be linked to the original artefact or its replicas (e.g., physical copies, web-based reproductions, projections, large interactive screens) and used as gateways to access the knowledge embedded in the artefact in any exhibition setting via smart devices. In the BYOD (Bring Your Own Device) era, via a quick-response (QR) code displayed in the exhibition caption, the camera of the visitor’s smart device can read the uniform resource locator (URL) and access the relevant EHM application. The user can also continue the experience on mobile and desktop devices after and outside the exhibition. This continuity of engagement allows EHM to involve the user in the co-design of the experience as experimented by the EU Research Project MeLa – European Museums in an Age of Migrations (refer to Capurro & Lupo, 2016, 93-89), online.

Being web-based, the EHM learning tools are accessible anywhere by anyone with an internet connection. Working on real-time knowledge

aggregation, the EHM information is constantly updated and possibly targeted on the visitor’s profile when logged into the system. A diagram in Fig. 1 illustrates the EHM workflow.

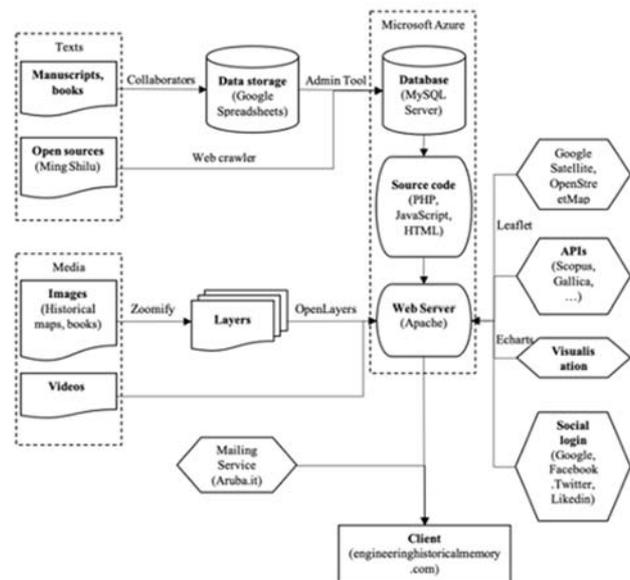


Fig. 1: Workflow of the EHM search drawn by Khoi Vu.

In the EHM application, the user can find (1) high-definition 2D and 3D digital reproductions of the artefacts explorable by free navigation or via graphs and geospatial views; (2) search engines for scholarly texts, images, and videos related to the individual entities on which the user is focusing interactively. As showcases, the following EHM applications can be presented. Each of them exemplifies a unique/different category of manuscript artefacts.

1. World Maps: [Fra Mauro’s Map of the World dated 26 August 1460](#) (refer to Fig. 2-4; and Nanetti & Benvenuti, 2019).
2. Archival Documents: [Pope Gregory X’s Privilege for the Holy Monastery of St Catherine of Sinai issued on 24 September 1274](#) (refer to Fig. 5; and Nanetti & Benvenuti, 2021).
3. Science, Technology, and Engineering Codices: [Francesco di Giorgio Martini’s Treatise I on Architecture on Civil and Military Architecture \(1475-1480 CE\): MS Ashb. 361 \(1482-1486 CE\) with notes and drawings by Leonardo da Vinci \(ca 1504 CE\) and MS Saluzzo 148 \(1480-1500\)](#) (refer to Fig. 6; and Nanetti, Benvenuti, Bigongiari, Radzi, & Bertocci, 2020).

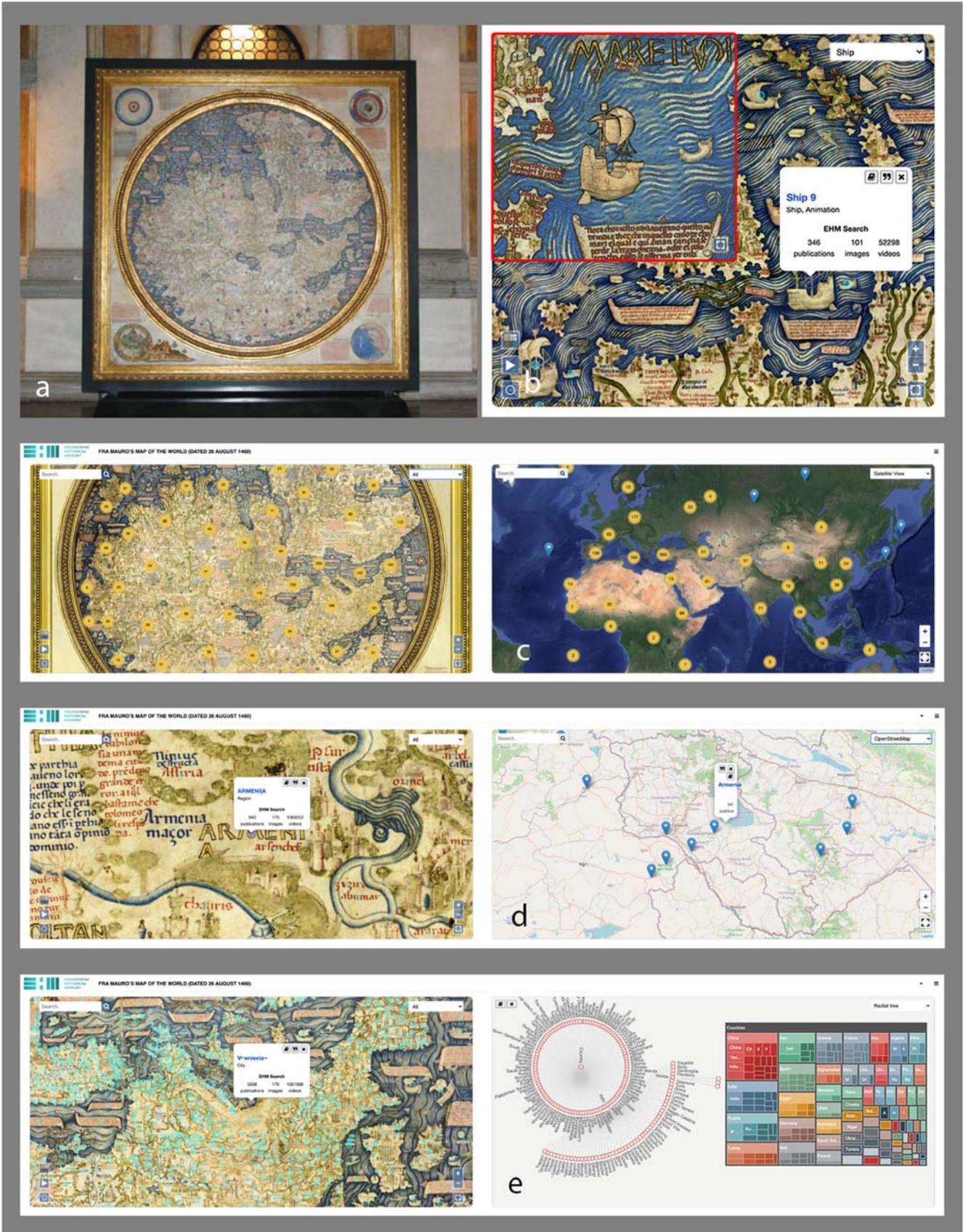


Fig. 2: [Fra Mauro's Map of the World dated 26 August 1460](#) (refer to Nanetti & Benvenuti, 2019). The map in the Marciana National Library (Venice, Italy): indecipherable to most visitors (a) and decoded by EHM (b). The EHM features for digital exploration and interactive decodification: deep zooming of the map and identification of the place names (c), critical edition, translations into English and Chinese (d), geospatial visualisations and infographics to browse information (c-e).

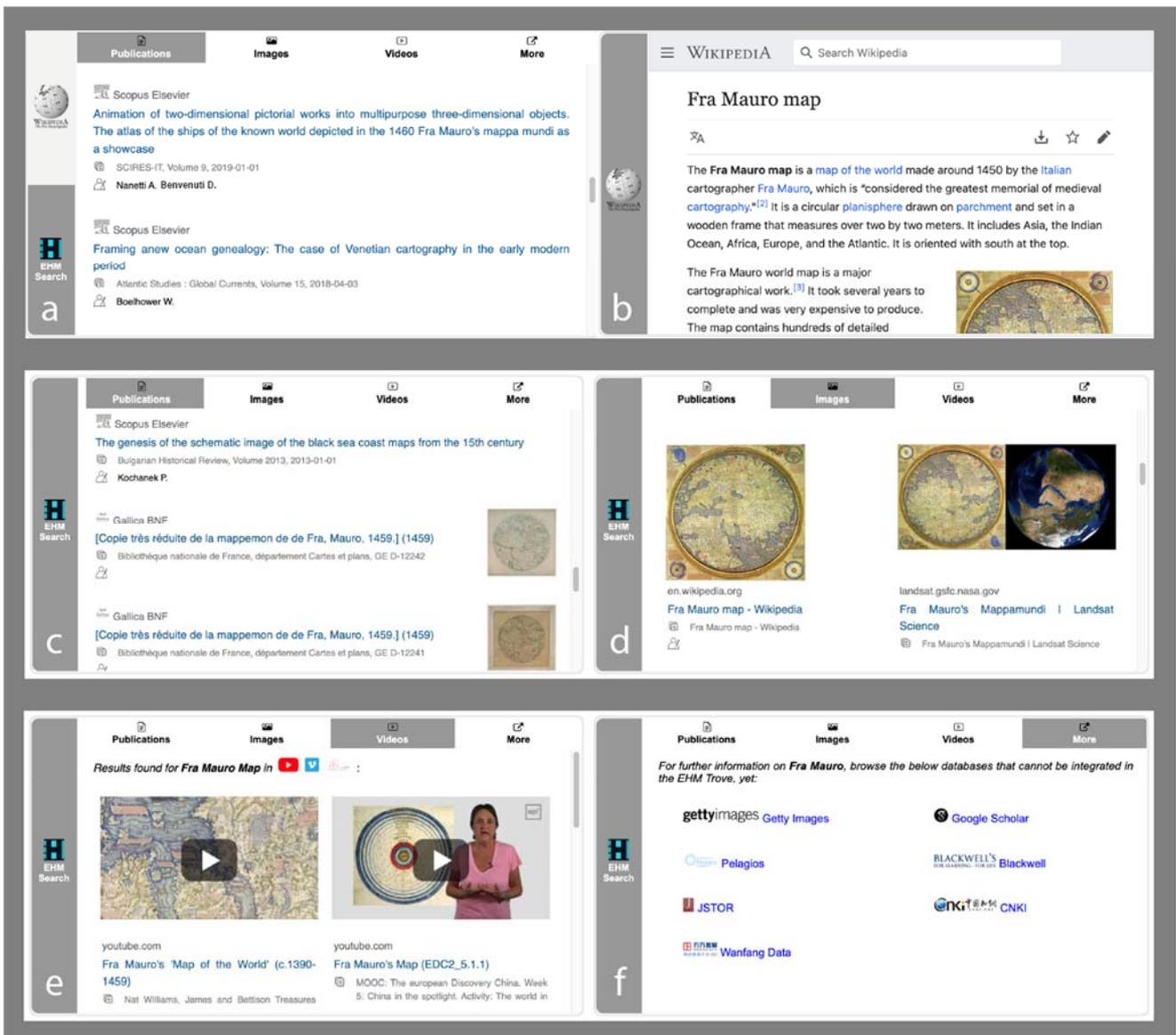
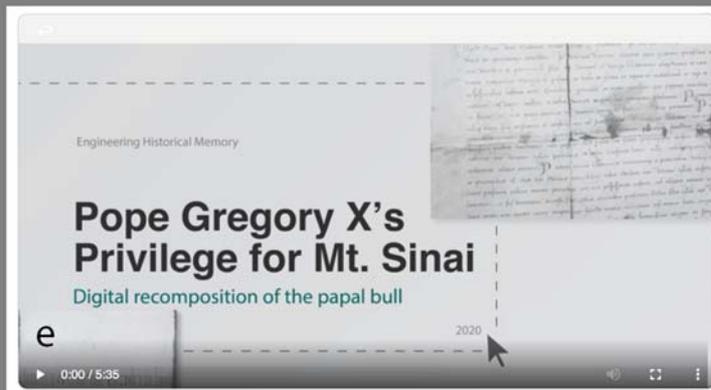
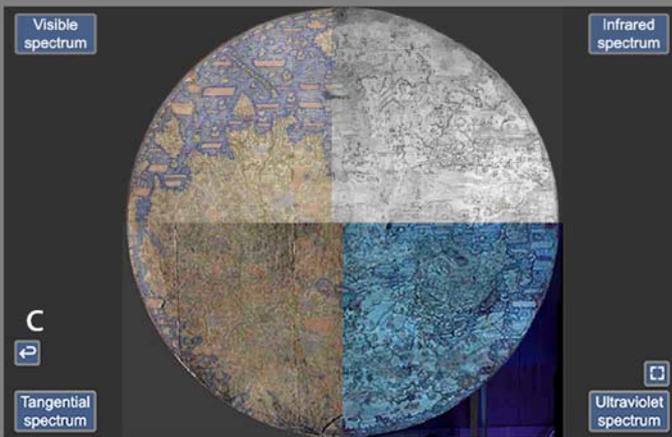


Fig. 3: Fra Mauro's Map of the World dated 26 August 1460 (refer to Nanetti & Benvenuti, 2019). Screenshots of the EHM search engine. The identifier of each item is the corresponding Wikipedia page (b). Search for scholarly publications from Europeana, Gallica, Taylor & Francis, Scopus-Elsevier, via API (a, c), images from Google Images and Bing Images via API (d), videos from YouTube, Vimeo, and I-Media Cities, via API (e), and guided search in other relevant resources that do not share their API publicly (f). An automated query consistent with the selected item is automatically filled to facilitate the search for these resources. Online repositories without API are not included in the EHM search (e.g., SmartHistory). The search feedback is filtered by scholarly relevance and is unprejudiced by any commercial purposes. – This research on the Fra Mauro's map was made possible by a collaboration between the School of Art, Design and Media of the Nanyang Technological University, Singapore (ADM-NTU), the Marciana National Library of Venice (Italy) within the framework of the Memorandum of Agreement signed on 30 March 2018, and the University of Venice Ca' Foscari within the framework of the Memorandum of Agreement signed in 2018. The digital images delivered to the authors by the Marciana National Library in March 2019 were taken by the professional photographer Francesco Mangiaracina (Padova, Italy) in 2009.

Fig. 4 (next page): Digital images with video documentation by Andree Hansen Wibobo. [Fra Mauro's Map of the World dated 26 August 1460](#) (a-d; reconstruction project; refer to Nanetti & Benvenuti, 2019). [Pope Gregory X's Privilege for the Holy Monastery of St Catherine of Sinai issued on 24 September 1274](#) (e-h; digital recomposition; refer to Nanetti & Benvenuti, 2021). Andrea Nanetti has photographed the original parchment during a palaeographic mission of the Centre of History and Palaeography of the National Bank of Greece Cultural Foundation (Director, Agamemnon Tselikas, 19-24 January 1994).



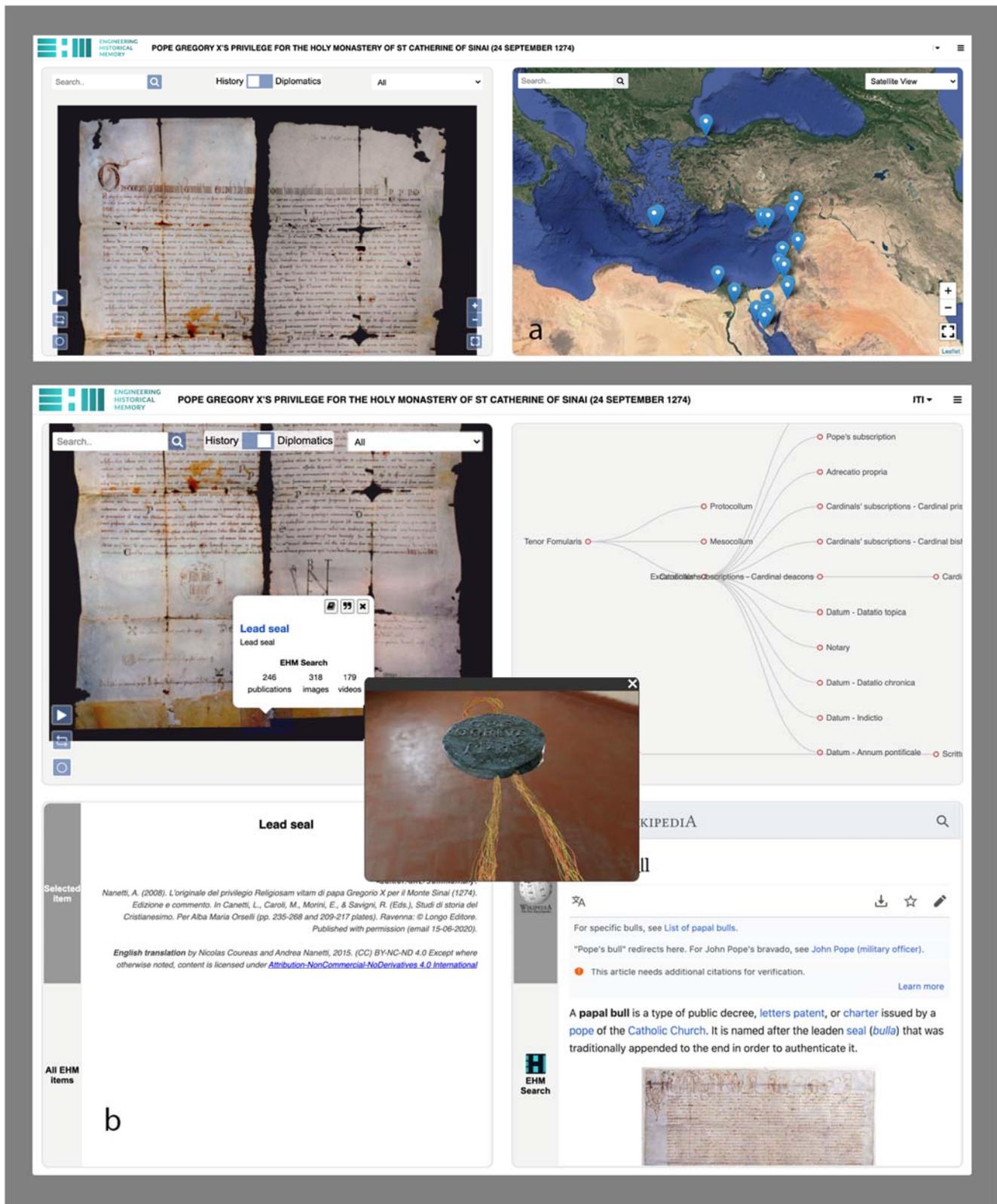


Fig. 5: Pope Gregory X's Privilege for the Holy Monastery of St Catherine of Sinai issued on 24 September 1274 (refer to Nanetti & Benvenuti, 2021). The application explores the document from historical (a, with geolocation of the properties) and diplomatics (b, with analysis of the juridical structure) perspectives. The modelling of the lost lead seal of Gregory X was made by the NTU-ADM undergraduate student Yap Wei Wen Marc based on images provided by the *Archivio di Stato di Venezia* in November 2020. At the School of Art, Design and Media of Nanyang Technological University, Singapore (ADM-NTU), the MA Student Xu Peisen created the customary web-based visualisation tool for the 3D model of the lead seal attached to the parchment with a silken cord. The digital object was uploaded on EHM in collaboration with the NTU-ADM Research Assistant Khoi Vu.

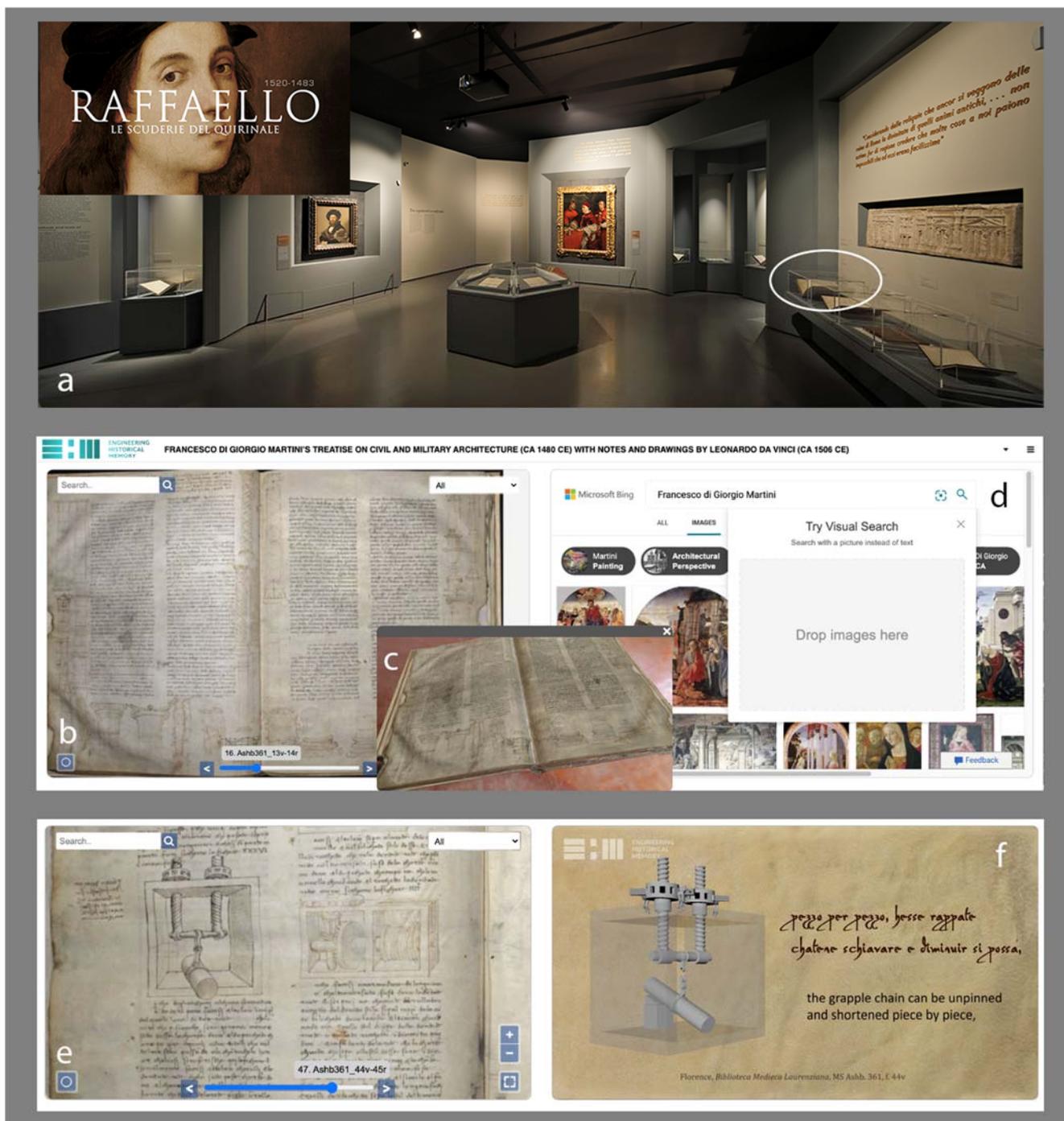


Fig. 6: [Francesco di Giorgio Martini's Treatise I on Architecture on Civil and Military Architecture \(1475-1480 CE\): MS Ashb. 361 \(1482-1486 CE\) with notes and drawings by Leonardo da Vinci \(ca 1504 CE\) and MS Saluzzo 148 \(1480-1500\)](#) (refer to Nanetti, Benvenuti, Bertocci, Bigongiari, & Vu, 2020). Francesco di Giorgio Martini's MS Saluzzo 148 (Turin, *Musei Reali*) opened at folios 70v-71r in an exhibition view (a) was photographed by Alberto Novelli (*Raffaello 1520-1483*, 5 March–2 June 2020, Hall 2, © Rome, *Scuderie del Quirinale*). EHM proposes tools to run online programmes that parallel the physical exhibition and continue it beyond the exhibition dates. The EHM tools presented in Figure 3 here above, along with the visual search under development in collaboration with Justin Dauwels at TUDelft (d), could enhance the visitor's experience with real-time and automatic searches for relevant publications, images, and videos. Furthermore, with the EHM tool, the users could decode the drawings watching animated videos, such as, for example, the one for a device to raise columns (e, f; MS Ashb. 361, folio 44v) created by Jessabel Teng Sheng Hui during the SGUnited Traineeship Programme (2020-2021) under the supervision of Andrea Nanetti. The digital photographs (b, c) of Martini's MS Ashb. 361, folios 13v-14r (Florence, *Biblioteca Medicea Laurenziana*) were taken by Matteo Bigongiari (University of Florence, Department of Architecture) with the permission of the *Biblioteca Medicea Laurenziana* in 2018. Thanks also to the kind support of the *Musei Reali*, that provided the digital images of MS Saluzzo 148 in 2020, the EHM application will allow the comparison of the drawings in the two early copies of Francesco di Giorgio Martini's *Trattato I* (refer to Nanetti, Benvenuti, Bigongiari, Radzi, & Bertocci, 2020, 21, Fig. 1).

7. Conclusions

The review of the secondary literature published in English about the strengths and weaknesses of the web-based learning tools available in museum systems as brought forward by the outbreak of the COVID-19 pandemic in 2020 requires extensive critical reading, which may be approachable later, once the pandemic is over. Indeed, studies discussed in *Section 2* found that online museums are valuable additions and complement to traditional museums but that a reliable method to evaluate online visits is still lacking (NEMO, 2020, 3). Furthermore, considering that the "current standard" might affect almost every museum-practice area in the future, this evolving environment necessitates updated performance metrics and, consequentially, investments (NEMO, 2020, 4). However, a general impression is that museums' experiences in adapting to the pandemic are building long-term innovation and re-imaging their societal role. A significant and common element is that museums are working on post-pandemic business models with new hybrid forms of visitor's experiences in which online programmes parallel physical exhibitions.

For the time being, in *Section 5*, this paper made some considerations on the strengths and weaknesses of the digital curation of manuscript artefacts in permanent and temporary exhibition settings based on the publications and practices reviewed in *Sections 2-4*. In 2020, museums worldwide increased their presence on the internet in general and especially on social networking apps and websites. As a result, museums were able to increase the number of accesses to their online initiatives and exhibitions. However, the overall feedback highlights that these big numbers seem to be ephemeral because the user experience has a concise life cycle. Users were engaged, and affiliations grew, but the attention span was appreciated as very short by the secondary literature.

Overall, notwithstanding the online push given to museums by the pandemic, it seems that there is still a lot to do in the identification of features from existing experiences to help to transform museums into flexible and receptive representatives of their societies (NEMO, 2020, 4). From a scholarly and educational perspective, what seems to be missing are tools to make the

exhibition setting (either physical, or online, or hybrid) become an open gateway to the treasure of human experiences embodied in the artefacts and supply this wealth of knowledge according to the specific interests and attitudes of each user, and according to the different occasions on which people desire or need to access heritage artefacts in archives, libraries, or museums.

The research outcomes presented in *Section 6* are the tools designed and developed within the online interactive system EHM for selected masterpieces (i.e., star objects) such as the Fra Mauro's map of the world, the original papal privilege issued by pope Gregory X for the monastic community of Mount Sinai, and the two early copies of Francesco di Giorgio Martini's *Treatise I*. Taking everything into account, the EHM tools go back to object-based curation to empower visitor-centred and post-critical museum experiences using AI and ML. Multiple and interactive narratives are tailored to the visitor's different motivations in reason of their diverse interests, expertise, and occasions of visiting museums. The EHM main innovation being an aggregation of relevant scholarly information automatically updated in real-time and possibly targeted on the visitor's profile when logged into the system.

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REFERENCES

- Agostino, D., Arnaboldi, M., & Lampis, A. (2020). Italian state museums during the COVID-19 crisis: from onsite closure to online openness. *Museum Management and Curatorship*, 35(4), 362–372. <https://doi.org/10.1080/09647775.2020.1790029>
- Altman, R. (2008). *A theory of narrative*. New York: Columbia University Press.
- Ballina, F. J., Valdes, L., & Del Valle, E. (2019). The Phygital Experience in the Smart Tourism Destination. *International Journal of Tourism Cities*, 5(4), 656–671.
- Bolick, C. M. (2006). Digital Archives: Democratizing the Doing of History. *International Journal of Social Education*, 21(1), 122-134.
- Capurro, R., & Lupo, E. (Eds.) (2016). *Designing Multivocal Museums. Intercultural Practices at 'Museo Diocesano, Milano'*. Research Project MeLa – European Museums in an Age of Migrations, funded within the European Union's Seventh Framework Programme (SSH-2010-5.2.2, project officer Mr Zoltán Krasznal). Milan: Politecnico di Milano, Department of Design.
- Ciecko, B. (2020). *4 Ways Museums Can Successfully Leverage Digital Content and Channels During Coronavirus (COVID-19)*. Retrieved from <https://www.aam-us.org/2020/03/25/4-ways-museums-can-successfully-leverage-digital-content-and-channels-during-coronavirus-covid-19/>
- Codex Atlanticus*. (2020). Bonera, M., Perozzi, S., Fracasio, F., Zerbini, G., Berto, D., Pontiroli, F., Bertolotti, G., & Nguyen, X. (2020). *Codex Atlanticus*. Retrieved from <https://www.codex-atlanticus.it/#/>
- Elassar, A. (2021). *Miss art museums? The Louvre just put its entire art collection online*. CNN Style. Retrieved from <https://edition.cnn.com/style/article/louvre-art-collection-free-museum-trnd/index.html>
- Falk, J. H. (2016). *Identity and the museum visitor experience*. Abington and New York: Routledge.
- Feldman, K. (2020). Leading the [USA] National Gallery of Art during COVID-19. *Museum Management and Curatorship*, 1-6. <https://doi.org/10.1080/09647775.2020.1790152>
- Gates, B. (2018). *The Da Vinci Codescope: A new way to look at Leonardo*. Retrieved from <https://www.gatesnotes.com/About-Bill-Gates/Codescope>.
- Google Arts and Culture. (2020). *Discovery Museum Google Street View Exploration*. Retrieved from <https://artsandculture.google.com/streetview/discovery-museum/hQHGq2lFEefXPA>
- ICOM. (2020). *How to Reach Your Public Remotely*. International Council of Museums (ICOM). Retrieved from <https://icom.museum/en/news/how-to-reach-and-engage-your-public-remotely>
- IMHS (2016). Museo Galileo - Institute and Museum of the History of Science (2016). *A Land Beyond the Stars: Amerigo Vespucci and Martin Waldseemür's Map of the World*. Retrieved from <https://exhibits.museogalileo.it/waldseemuller/index.html>
- IMHS. (2021). Museo Galileo - Institute and Museum of the History of Science (2021). *Mostre Virtuali (Virtual Exhibitions)*. Retrieved from <https://www.museogalileo.it/it/biblioteca-e-istituto-di-ricerca/progetti/mostre-virtuali.html>
- Murawska-Muthesius, K. (2016). *Masterpieces and the Critical Museum*. In K. Murawska-Muthesius & P. Piotrowski (Eds.), *From Museum Critique to the Critical Museum* (pp. 99-114). Abington and New York: Routledge (first published by Ashgate Publishing in 2015).

Murawska-Muthesius, K., & Piotrowski, P. (Eds.). (2016). *From Museum Critique to the Critical Museum* (pp. 195-214). Abington and New York: Routledge (first published by Ashgate Publishing in 2015).

Nanetti, A., Falchetta, P., & Vu, N. K. (Eds.) (first release, November 2019). *Fra Mauro's Mappa Mundi (dated 26 August 1460)*. Vernacular Venetian text and commentary by P. Falchetta, with translations into English and Mandarin supervised by P. Falchetta and D. Beltrame, respectively. Interactive navigation of the high-resolution digital replica with deep zoom feature. 3D NPR models by G. Wee supervised by D. Benvenuti of the ships depicted on the map. Real-time automatic update for related scholarly publications, images, videos. Retrieved from <https://engineeringhistoricalmemory.com/FraMauro.php>

Nanetti, A., & Benvenuti, D. (2019). Animation of two-dimensional pictorial works into multipurpose three-dimensional objects. The Atlas of the Ships of the Known World depicted in the 1460 Fra Mauro's mappa mundi as a showcase. *SCIRES-IT (SCientific RESearch and Information Technology)*, 9(2), 29-46.

Nanetti, A. (first release, September 2020) *About Engineering Historical Memory*. Retrieved from <https://engineeringhistoricalmemory.com/About.php>

Nanetti, A., Benvenuti, D., Bertocci, S., Bigongiari, M., & Vu, N. K. (Eds.) (first release, October 2020). *Francesco di Giorgio Martini's Treatise I on Architecture on Civil and Military Architecture (1475-1480 CE): MS Ashb. 361 (1482-1486 CE) with notes and drawings by Leonardo da Vinci (ca 1504 CE) and MS Saluzzo 148 (1480-1500)*. Interactive navigation of the high-resolution digital replicas of MS Ashb. 361 and MS Saluzzo 148 with a deep zoom feature and real-time automatic update for related scholarly publications, images, videos. 3D photogrammetric survey and reconstruction by M. Bigongiari of the manuscript Ashb. 361, optimisation and customary web-based visualisation tool for the 3D model by P. Xu supervised by D. Benvenuti. Edition of the vernacular Italian text by A. Nanetti based on the diplomatic transcriptions by P. Marani and M. Mussini. Critical edition of the annotations by L. da Vinci. English translations by J. Melville-Jones and A. Nanetti. Commentary on the drawings by A. Corso, S. Bertocci, A. Nanetti. Animations by J. S. H. Teng supervised by A. Nanetti and S. Bertocci of the drawings related to the annotations by L. da Vinci. Categorisation and critical comparison of the drawings of the two MSS by S. Bertocci and M. Bigongiari. Interactive navigation of the drawings with real-time automatic template matching for similar images on Europeana. Retrieved from <https://engineeringhistoricalmemory.com/FGM.php>

Nanetti, A., Benvenuti, D., Bigongiari, M., Radzi, Z., & Bertocci, S. (2020). Animation for the Study of Renaissance Treatises on Architecture. Francesco di Giorgio Martini's Corinthian Capital as a Showcase. *SCIRES-IT (SCientific RESearch and Information Technology)*, 10(2), 19-36.

Nanetti, A., & Vu, N. K. (Eds.) (first release, June 2020). *Pope Gregory X's Privilege for the Holy Monastery of St Catherine of Sinai (24 September 1274)*. Digital recomposition of the parchment with video documentation by A. H. Wibobo. Edition of the Latin text, diplomatics and history commentaries, interactive exploration of the *tenor formularis*, and geolocation of the properties by A. Nanetti. 3D model of the lost lead seal by M. W. W. Yap and customary web-based visualisation tool for the 3D model by P. Xu supervised by D. Benvenuti. Interactive navigation of the high-resolution digital replica with a deep zoom feature and real-time automatic update for related scholarly publications, images, videos. Retrieved from <https://engineeringhistoricalmemory.com/MountSinai.php>

Nanetti, A. (2021). Defining Heritage Science. A Consilience Pathway to Treasuring the Complexity of Inheritable Human Experience through Historical Method, AI and ML. *Complexity*, vol. 2021. <https://doi.org/10.1155/2021/4703820>

Nanetti, A., & Benvenuti, D. (2021). Engineering Historical Memory and the Interactive Exploration of Archival Documents. The Online Application for Pope Gregory X's Privilege for the Community of Mount Sinai (1274) as a Prototype. *Journal Article*. Forthcoming.

- NEMO. (2020, 12 May, a). *Survey on the impact of the COVID-19 situation on museums in Europe. Final Report*. Network of European Museum Organisation (NEMO). Retrieved from https://www.nemo.org/fileadmin/Dateien/public/NEMO_documents/NEMO_COVID19_Report_12.05.2020.pdf
- NEMO. (2020, 12 May, b). *Survey on the impact of the COVID-19 situation on museums in Europe. Final Findings and Recommendations*. Network of European Museum Organisation (NEMO). Retrieved from [https://www.nemo.org/fileadmin/Dateien/public/NEMO_documents/Final Findings and Recommendations CVOID19 12.05.2020.pdf](https://www.nemo.org/fileadmin/Dateien/public/NEMO_documents/Final_Findings_and_Recommendations_CVOID19_12.05.2020.pdf)
- NEMO. (2021, 11 January). *Follow-up survey on the impact of the COVID-19 pandemic on museums in Europe. Final Report*. NEMO (Network of European Museum Organisation). Retrieved from [https://www.nemo.org/fileadmin/Dateien/public/NEMO_documents/NEMO_COVID19 FollowUpReport 11.1.2021.pdf](https://www.nemo.org/fileadmin/Dateien/public/NEMO_documents/NEMO_COVID19_FollowUpReport_11.1.2021.pdf)
- Reeve, J., & Woollard, V. (2006). Influences on Museum Practice. In C. Lang (Ed.), *The Responsive Museum: Working with Audiences in the Twenty-First Century* (pp. 5-17). Hampshire, England: Ashgate Publishing Limited.
- Samaroudi, M., Echavarria, K. R., & Perry, L. (2020). Heritage in lockdown: digital provision of memory institutions in the UK and US of America during the COVID-19 pandemic. *Museum Management and Curatorship*, 35(4), 337–361. <https://doi.org/10.1080/09647775.2020.1810483>
- Science Museum Group. (2020). *Science Museum Group*. Sketchfab. Retrieved from <https://sketchfab.com/sciencemuseum>
- Tan, A. T. E. (2020, 27 August). *Surveying and Addressing COVID-19's Impact on Museums in Singapore*. International Council of Museums (ICOM). Retrieved from <https://icom.museum/en/news/surveying-and-addressing-covid-19s-impact-on-museums-in-singapore/>
- The British Museum*. (2020). *The British Museum*. Sketchfab. Retrieved from <https://sketchfab.com/britishmuseum>
- The Getty*. (2020). Last-Minute Michelangelo. J. Paul Getty Center, Los Angeles. *Apollo. The International Art Magazine*. Retrieved from <https://blogs.getty.edu/iris/lastminute-michelangelo/>
- UNESCO. (2020, May). *Museums around the World in the face of COVID-19*. United Nations Educational, Scientific and Cultural Organization (UNESCO). Retrieved from <https://unesdoc.unesco.org/ark:/48223/pf0000373530>
- Virtual Vizcaya*. (2020). *Virtual Vizcaya*. Vizcaya Museum and Gardens. Retrieved from <http://virtualvizcaya.org/index.html>