

Article

Assessing the Readiness of Cultural Heritage Institutions' Digital Data to Engage with the European Collaborative Cloud for Cultural Heritage Based on Late Bronze Age Cypriot Figurines as a Case Study

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Abstract

According to its published mission, the European Collaborative Cloud for Cultural Heritage (ECCCH), the most recent flagship initiative of the European Commission currently being developed by the EU-funded project ECHOES, is "...a digital ecosystem designed to serve as a platform for cultural heritage professionals, researchers, and institutions across Europe... to unify Europe's fragmented cultural heritage sector through advanced digital collaboration...". While recognizing that "...one of the most persistent challenges in the European cultural heritage sector is the dispersion of data in incompatible formats and isolated institutional practices...", the ECCCH advances "...a unified approach (that) will radically transform and greatly facilitate ... collaborative research...", promoting the engagement with small, peripheral Cultural Heritage (CH) institutions and providing (tangible and intangible) CH data under their custody. The article describes an experiment in assessing the usefulness of online accessible digital data on a specific type of CH objects, namely Cypriot Late Bronze Age figurines, for synthetic research on their socio-economic and cultural roles, as provided by CH institutions through their digital catalogues. Most of the ca. 170 figurines unearthed so far were found in Cyprus, where they were also produced. Out of these, ca. a third are hosted in museums in Cyprus, and the others are dispersed in some 36 museums, primarily in the UK, museums across ten EU countries, the USA and the Russian Federation. Less than half of them provide information on these figurines through their digital, open-access collections catalogue. The study reported here looked into the metadata of the museums' online catalogues and their possibility to be expressed by the ECHOES' CIDOC CRM-based ontology, as well as the relevance of the provided content for archaeological research. Finally, using freely available commercial AI models, the experiment preliminarily explored the relevance of their use in synthetic research based on museums' data. The results have shown that museums' online catalogues describing the Cypriot figurines examined are largely constrained by the Object ID documentation standard, conceived to identify and record cultural goods and created as a practical tool for facilitating the recovery of stolen cultural goods, providing limited information necessary for conducting archaeological research on them.

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1. Introduction

1.1. *The Collaborative Cloud for Cultural Heritage*

Following the publication of the Report on a European collaborative cloud for cultural heritage [1], the European Commission granted ECHOES, a consortium of more than 50 institutions around Europe, the mission to set the foundations for the establishment of the European Collaborative Cloud for Cultural Heritage (ECCCH), “...a shared platform designed to facilitate collaboration among heritage professionals and researchers, enabling them to modernize their workflows and processes ... (it) will offer access to data, cutting-edge scientific and training resources, and advanced digital tools...” [2]. The project started in early 2024 and will have a duration of 60 months. One of its challenges is to provide a platform for museums in remote areas and those of small to medium size to share their data as well. Thus, a major effort is directed towards a much-needed digital environment for CH researchers and professionals, where they will be able to access and process digital data, making use of advanced tools to create new knowledge on the research, preservation and valorization of CH. This step requires that a substantial number of artefacts, monuments and sites hosted, curated and managed by the numerous CH museums and institutions in Europe (ca. six thousand, according to the European Group of Museum Statistics) be digitized, and that the available digital content has a clear scientific value for interested communities of researchers and professionals.

Consequently, following expected paradigm shifts in CH research taking advantage of available AI models and tools, there is an imperative need for access to high-quality CH research data to be made accessible to such AI agents, with the ECCCH considering it a priority. AI largely relies on Machine Learning, an approach primarily involving advanced statistical and mathematical principles that require access to data to optimize its algorithms; Deep Learning, involving neural networks that simulate human brain activities and thus requiring the use of large-scale training data and reasoning models; and Natural Language models, necessitating access to a large amount of textual data in order to extract valuable information. Thus, it is clear that the success of intelligently engaging with AI models to build new knowledge in CH relies on providing AI agents access to large amounts of data largely generated by peer-reviewed research.

Despite numerous efforts coordinated by the European Union for providing policies, norms and digital platforms for the digitization and delivery of open access to its CH [3,4] and a plethora of scientific papers detailing the implementation of such processes [5–11], the amount and the content of digital data available, as provided by CH institutions and museums, is still lacking the necessary depth and breadth needed for its re-use in scientific and professional contexts. As shown below in the analysis of a case study, digital catalogues of museums’ collections, predominantly based on the OBJECT ID data model (see below), often provide a general description of artefacts, with information mainly related to curatorial and management aspects and not necessarily for research purposes.

The main obstacles in conducting exhaustive research based on openly available digital content published in museums’ catalogues are therefore the scarcity of high-quality documentation material (e.g., 3D models, images, etc.) of the investigated artefacts, a poor description of artefacts (usually de-contextualized from their original socio-cultural/archaeological contexts), and the overall limited number of artefacts digitized. Consequently, such descriptions often lack the consistency of using agreed-upon terminologies, shared thesauri and data models, thus complicating attempts at unifying access to their

digital collections. Moreover, ongoing digitization efforts in museums are still limited in what regards 3D documentation of artefacts, due to a variety of factors such as suitable infrastructures and related data services, know-how or adequate equipment and dedicated professional staff.

1.2. Description of the Case Study

The case study analyzed here regards an iconic Cypriot heritage asset, known in the professional literature primarily under two (converging) terms: Base Ring II Ware female figurines and Type B flat-head figurines [12–14] (or, in short, BRFB for this article). They were produced primarily for an insular use during the Late Bronze Age, the local chronology term being Late Cypriot II–IIIA (ca. 15th–12th centuries B.C.E). While they were presented in several catalogues [13,15–17], analyzed in detail in a PhD thesis [14], and amply discussed in numerous publications [18–28], most descriptions rely on the same early documentation and descriptions, often involving pictures lacking clarity or focus and based on qualitative, visual investigations. Moreover, up to today, there are no 3D models of any of these figurines available for a detailed shape analysis, and the catalogues describing them are available only in hard copies.

Since the second half of the 19th century and onwards, some 170 BRFB have been uncovered during the long history of archaeological excavations (both systematic and un-systematic) in Cyprus. Ca. a third are currently hosted in Cyprus, primarily curated by the Cyprus Department of Antiquities at its Cyprus Museum, a few are in two private museums, while the remaining five belonged to a private collection that was lost during the early days of the 1974 military events in Cyprus, which led to the looting and pillage of many heritage monuments and collections from the conflict zones in the northern part of the island. As of today, there is no open-access information available on any of the BRFB hosted in Cyprus.

The remaining BRFB are nowadays hosted in some 34 museums in 16 EU countries, in Switzerland, the UK, the USA, Canada, Israel and the Russian Federation (see below); the richest collection outside the island is kept in UK museums, primarily the British Museum. Ca. a third of these museums offer access to their digital collections featuring BRFB, providing information on less than a quarter of the total unearthed BRFB. As described below, the most detailed descriptions are provided by the British Museum in London, the Medelhavsmuseet in Stockholm and the Louvre in Paris. Thus, anyone wishing to conduct synthetic research on BRFB, based on openly available documentation material, is limited to the images of figurines as published on the digital catalogues of the few museums mentioned above, often focusing on providing general information on the objects, including curatorship, archiving and management details.

The BRFB collection is emblematic of the current grand challenges of investigating heritage assets related to countries with a long history of archaeological explorations, such as Cyprus, which often resulted in the extraction of a large amount of material culture from their country of origin and its dispersion across the globe. Research on BRFB requires a multi-disciplinary approach involving archaeology, history of religion, heritage science, computer-assisted shape analysis, history and iconology. Aspects related to their materiality, provenance, technologies of production and techniques of manufacture, alongside archaeological context investigation, may reveal aspects about their socio-cultural and economic role(s), and, in a broader context, insights into Late Bronze Age societies and their systems of beliefs (cultic or symbolic). Nowadays, 2/3 of the BRFB are stored outside their country of origin (Cyprus), in large or small-scale and peripheral museums, providing varying access to information, as detailed below.

1.3. Research Aims

The main aims of the work presented below can thus be summarized as follows:

1. Explore the suitability of BRFB descriptions provided by museums' online catalogues as the basis for synthetic research on BRFB aimed at reconstructing their past socio-economic and cultural roles.
2. Examine the accuracy of summaries produced by freely available commercial AI models, based on information on BRFB provided by CH museums.
3. Verify the readiness of the ECHOES' ontology to capture the entirety of the museums' catalogue metadata on BRFB.

2. Methodology and Data Collection

2.1. Framing the Synthetic Research on BRFB

Understanding the socio-cultural, spiritual and economic roles BRFB has played in past societies [29] requires framing a methodology that covers, among others, aspects related to the description of their archaeological context, information on their materiality, use and function [30], as well as gathering theoretical knowledge on cultural anthropological aspects related to cultic and symbolic systems [31] in prehistoric societies of the Late Bronze Age [32] as well as potentially related written sources [33]. Thus, a basic question would be “which is the nature (essence), in terms of function, social role and spiritual relevance, of these objects?” (Figure 1), followed by the question “how do we study these objects?” (Figure 2). This helps formulate a hypothesis about the socio-cultural and spiritual roles these figurines played in the past, a hypothesis which will have to be tested against the data available (archaeological remains, ancient written sources and ethnographic studies). Once the research aims are clearly stated, the hypothesis formulated and the methodology framework defined, the next step is to search for the data needed to test the hypothesis.

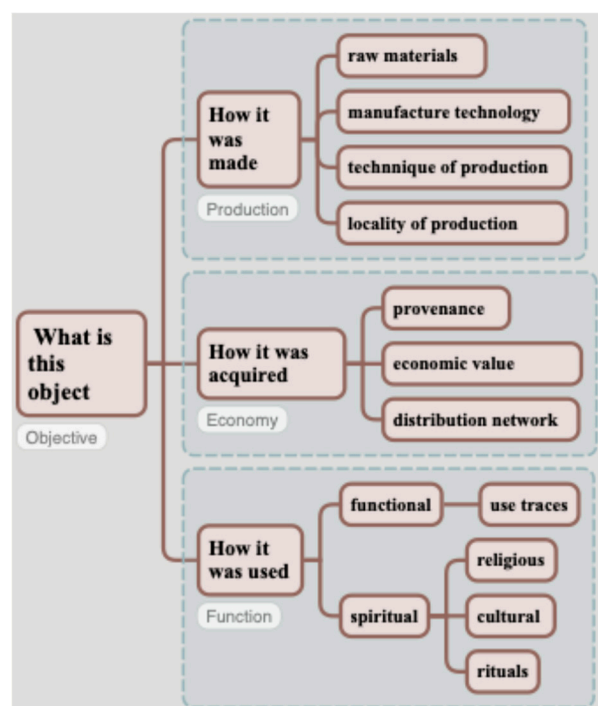


Figure 1. What is the object under investigation (blue rectangles delineate blocks of each of the main sub-questions formulating the main objective: production, economy and function, respectively).

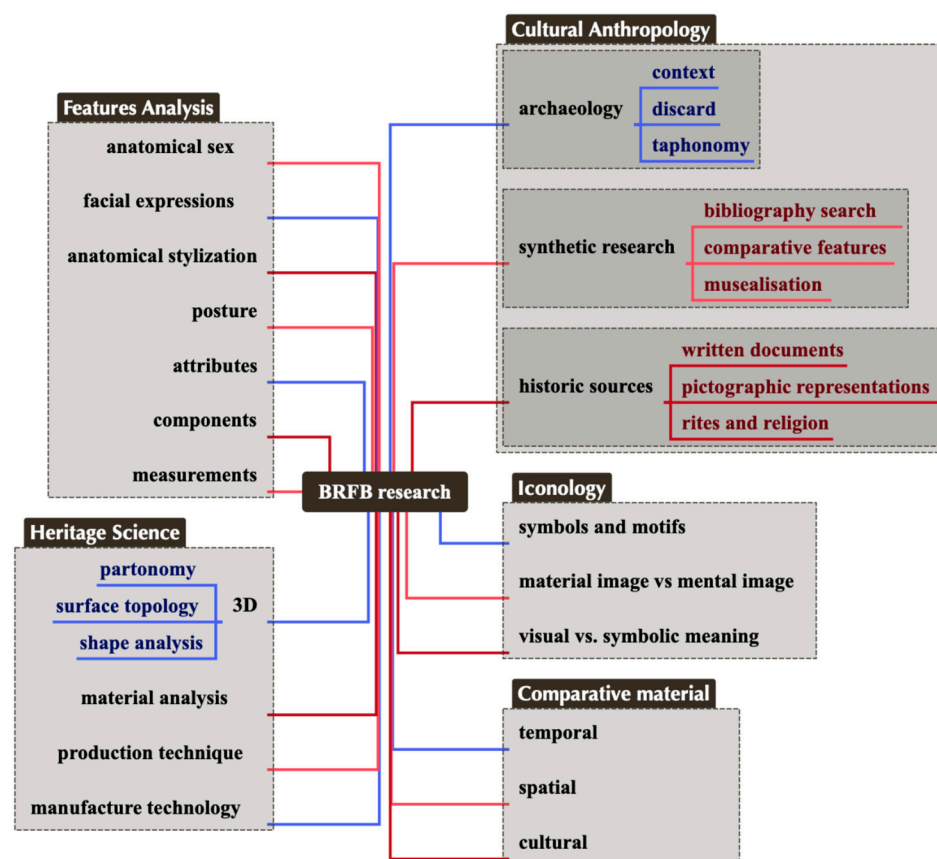


Figure 2. BRFB research components.

2.2. Data Requirements for Synthetic Research on BRFB

Synthetic research exploring the socio-economic and cultural roles BRFB has played in the past requires access to data or detailed bibliographic references describing the objects' provenance (archaeological context) and access to documentation material (including clear, calibrated images from various angles, 3D models, and access to any additional investigations conducted, e.g., on their materiality, production mode, etc.). In broader terms, requirements for research include, among others, access to primary excavation records, bibliographic sources on results of previous research, rich objects' descriptions, etc.

Consequently, objects' descriptions, and in more general terms, datasets of any kind, should be published using open, interoperable formats using controlled vocabularies, thesauri and terminologies agreed by communities of use, requirements broadly covered by recommendations for publishing data aligned with the FAIR data principles. CIDOC-CRM [34], the ISO standard ISO 21127:2023 for information and documentation, is the reference ontology for the interchange of cultural heritage information upon which specific extensions or domain-related ontologies, such as ICON [35] AAAo [36] or SDHSS [37], and others, are built. HDTO, the Heritage Digital Twin Ontology (see below), has been chosen as forming the base for the ECCCH's Knowledge Base and related data model, being aligned with the ECCCH's requirements as set in [1], presented in [38–40] and applied in [41,42]. As detailed below, it is based on and it is compliant with CIDOC CRM, suggesting a few extensions to specifically address requirements in building digital commons and ensuring their digital continuum within ECCCH's cloud environment.

Accordingly, we applied a three-stages cumulative approach in exploring the first aim of this research: [a] compile a list of museums hosting BRFB and providing online catalogue descriptions on them; [b] identify which of the museums' entries contain information relevant for research on BRFB (as per Figures 1 and 2); [c] check this information

primarily in terms of data provenance, completeness and consistency across museums. We thus moved beyond the technological challenges of mapping between data models, access to data or ontology alignments, and looked into the actual information provided. Considering one of the main goals of the ECCCH is to provide access to data and tools for research in CH, we primarily investigated the potential contribution of museums' data (see also [43]) when conducting synthetic research, as described above.

2.3. Identifying Museums Hosting BRFB Using Dedicated Online Platforms

There are two main platforms offering online access to heritage digital content: Europeana, according to its main page "...providing access to Europe's digital cultural heritage...", in order to "search, save and share art, books, films and music from thousands of cultural institutions [44] and Google Arts & Culture [45] (hereafter GA&C), a Google platform launched in 2011 (initially as Google Art Project) providing access to information on artworks, heritage sites, artefacts, virtual exhibitions or storytelling narratives from a broad range of heritage institutions worldwide. While Europeana relies mainly on EU funding to maintain itself and to gather content from a broad range of aggregators (heritage institutions providing metadata about heritage assets), GA&C establishes partnerships with cultural institutions for creating and publishing content as well as develops technologies to improve documentation and access to this content [46,47].

Europeana, the largest coordinated effort in providing open access to digital data on the CH of Europe, and one of the flagship initiatives of the European Commission for CH, has been gathering metadata information on heritage assets for almost two decades, from an impressive number of ca. two thousand cultural institutions, and currently hosting 60+ million records. It uses the EDM—Europeana Data Model to describe its content, which is a metadata schema largely based on CIDOC CRM. Various assessments highlighted Europeana's major challenges on metadata or copyright aspects [48–53], primarily limiting its use for in-depth CH research.

The first step in searching for open access to data on BRFB is to find the most efficient terms for the search. The first choice is to search using specific terms used in various scientific publications on BRFB. On the other hand, the second choice is to search for generic terms, such as clay figurines, and, through a filtering process, narrow the search until satisfactory results are obtained. Table 1 shows the search results obtained in Europeana and GA&C, using both a generic and a specific term.

Table 1. Comparison between Europeana and GA&C search results.

Term Searched	Europeana		GA&C	
	Results	Relevant	Results	Relevant
Cypriot late bronze age terracotta female figurine	1	1	7	3
Cypriot base ring female figurine	9	6	0	0

The significant differences in the results denote an interesting trend. GA&C returned 7 results for the first term, out of which 3 were relevant, the other 4 being objects that are not figurines or not from the Late Bronze Age. The 3 relevant items were published in collaboration with the Metropolitan Museum of Art, the Brooklyn Museum and the Glencairn Museum (all US-based institutions). A single item was found in Europeana, correctly identified, and provided by the Medelhavsmuseet in Stockholm.

Excluding the words "terracotta" (referring to a technique of manufacture and material) and "late bronze age", denoting an archaeological period/culture, and replacing them with a term used for describing a specific type of Cypriot ceramic ware (base ring) returned very different results. GA&C found no items, while Europeana identified 9 items, 6 of them being relevant and representing the entire collection of such figurines indexed

by it (4 provided by Medelhavsmuseet and 2 by the Kunsthistorisches Museum in Vienna. Thus, Europeana is a useful starting point to identify sources for additional information on BRFB.

2.4. Identifying Museums Hosting BRFB Using Scientific Publications

The search for relevant scientific literature with Google Scholar and using the two terms mentioned above harvests some 18,000 results for each, none of them pointing to the catalogues mentioned above [12–17] among the first choices. Consequently, one looking to gather information on the current location of figurines in various CH institutions hosting them and consequently obtain access to documentation material as published by these institutions, must browse the various scientific articles discussing aspects related to them (e.g., [18–29]) and manually extract from there the desired information. The result of this effort is presented in Table 2 below.

Table 2. Cultural institutions hosting BRFB.

Country	Museum	Nr. of Items	
		All	Online
Austria	Kunsthistorisches Museum, Vienna (KMV)	2	2
Denmark	Nationalmuseet	2	
France (N _{tot} = 4)	Louvre	2	1
	Château Borély	1	
	Musée de la Céramique, Paris	1	
Germany	Antikensammlung Museum, Berlin	1	
	Berlin University Museum (?)	1	
Greece	National Archaeological Museum	1	
Ireland	National Archaeological Museum	1	
	The Classical Museum, UCD	1	
Italy	Museo Civico di Storia ed Arte	1	1
	Museo Archaeologico di Firenze	1	
Netherlands	Allard Pierson Museum	1	
Sweden (N _{tot} = 5)	Medelhavsmuseet (MMS)	4	4
	Antikmuseet, Lund	1	
Switzerland	Musée d'art et d'histoire, Geneva	1	1
Israel	Israel Museum	1	1
Russia	Pushkin State Museum	1	
United Kingdom (N _{tot} = 33)	Birmingham Museum and Art Gallery	1	
	Wolverhampton Museum (WM)	1	1
	Leeds Museum	1	
	Royal Albert Memorial Museum, Exeter	1	1
	Ashmolean Museum	2	2
	British Museum (BM)	13	13
	National Museums of Scotland (NSM)	1	1
	Pitt-Rivers Museum (PRM)	3	3
United States (N _{tot} = 6)	Metropolitan Museum of Art (MET)	3	3
	Princeton University Art Museum	1	
	Museum of Fine Arts, Boston	1	
	Brooklyn Museum	1	1
Canada	Ontario Museum	1	1
Cyprus (N _{tot} = 68)	Cyprus Museum	62	
	Pierides Museum	4	
	Leventis Museum	2	

Total	16	34 (15 with online catalogues)	162	36
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In addition, according to the catalogues mentioned above and the online search, 10 figurines were sold to private collectors by various auction houses, as described in Table 3.

Table 3. BRFB sold at auction houses (* the term Provenance here denotes the history of ownership/previous owners, as per the descriptions of auction houses, and not the geographic provenance of the objects).

Auction House	Lot	* Provenance
Bonhams	115	The Matantos Collection of Classical Antiquities, formed during the late 1950s and 1960s.
	29 *	American private collection, Tennessee, acquired in the 1970s–1980s.
	53	D. R. collection, England, acquired prior to 1969.
	568	<i>Unspecified</i>
Christoph Bacher	Ref: 2063	Private collection Surgeon-General Dr. Josef Mayer-Riefenthaler, Vienna, Austria. Acquired in Cyprus in the 1960s, during his deployment as UN soldier.
Christie's	78	The Desmond Morris collection.
	79	
	50	Alfred E. Mirsky (1900–1974).
	8	C. Gillet (1879–1972), Lausanne thence by descent to his son, R. Gillet (1913–2001), Paris.
Sotheby's		Sotheby's London Sales Cat. 11 December 1989.

Finally, the Google images search [54] correctly identified a few BRFB, among them 4 from online museum catalogues (of the Israel Museum, the MET, the Brooklyn Museum and the Medelhavsmuseet), two from auction houses (Christoph Bacher and Bonhams), one entry from Wikidata, indexing a Louvre-hosted item, and one item published on Flickr and hosted at the Ashmolean Museum.

2.5. Organization of Information on BRFB in Museums' Online Catalogues

Looking at the BRFB descriptions, as published by the museums mentioned in Table 2, several strategies were identified for presenting the information and its level of detail (see below). The Medelhavsmuseet and its Carlotta system [55] are outstanding, providing a broad range of structured information on its exhibits, followed by The Louvre and the British Museum (see below).

Broadly, five main categories of data emerge: (a) administrative, including object's inventory number, its broad classification (type of object) and the collection it belongs to; (b) object provenance, including information on its place and date of discovery; (c) archaeological description on the object, which details its material and technique of manufacture, size, general depiction, cultural context, conservation state and publication; (d) its history of ownership (past and current owners and acquisition mode and date); and (e) curatorial aspects, which include where the object is exhibited and past exhibitions it was part of. Thus, categories (b) and (c) are the primary source for synthetic research on BRFB, as per the first aim of this research.

The information published by auction houses that sold BRFB consists primarily of a short text description of the object, its size and materiality, its history of ownership and information on where it was published.

2.6. AI-Based Information on BRFB

As part of the effort summarized in the first aim of the research reported here, and due to the growing engagement of AI models in research activities across a broad range

of disciplines, we investigated the ability of some such models to gather information on BRFB. It should be noted here that generally none of the AI models tested had direct access to museum online catalogues, nor to peer-reviewed research publications (books, journal papers and alike), and overall, they relied on a variety of websites where BRFB descriptions have an unsupervised scientific presence.

Several commercial AI models (Perplexity's Comet browser, ChatGPT, and Gemini) were posed the request to provide a list of museums hosting BRFB; the input terms for the search were the specific terms used in the related literature, such as "flat-head" and "base-ring" terracotta figurines. The prompt posed was "please provide a list of museums hosting Cypriot figurines known in the literature as flat-head or base-ring figurines". Grok stands out, with more than 65 search sources and compiling a list of 9 museums. ChatGPT found 8 museums, using 5 sources, while the other two found 6 museums each, Comet consulting 10 sources and Gemini 5. The British Museum stands out, being the only museum that appears recurrently as a source of information for the checked AI models, enabling access to its online catalogue. Even if we consider only the 15 museums with online catalogues on BRFB, it is clear that the lists of museums hosting BRFB provided by the AI models are low.

In the next step of examining information provided by AI models, we asked ChatGPT, Gemini and Grok to provide a synthetic description of BRFB, based on summarizing the museums' texts published in their category "description". These text entries had to be manually extracted from each online catalogue, since none of the AI models used had access to the museum catalogue entries themselves (for consultation of these museum entries, please consult the links provided in Table 2). As a follow-up, each of the three AI models was further asked to compile a summary of each of these three syntheses. Among the results (see below), the summary provided by Grok was the most accurate; ChatGPT returned an inflated text with many irrelevant additions, possibly due to an attempt to compile a pleasant-to-read, credible narrative, while Gemini omitted information, providing a short, oversimplified text.

3. Results

3.1. Data Search Using Large-Scale Online Platforms

Taking a closer look at the information provided by Europeana, it is interesting to note the discrepancy in the search results using slightly different approaches. While the generic search term "Cypriot female figurine" returned (rightfully) a high number of results (230), which included the relevant BRFB ones, limiting the search to a specific timeframe and material type (Bronze Age and terracotta) yielded a single relevant result. However, when replacing these keywords with a specific term (base ring), commonly used in the related scientific literature [43], nine results were obtained, out of which six were correct, two were a different type of object (a ceramic vessel, from a different period) and one was a sculpture from a different period. The final relevant results for this study are two items at the KMV and four objects at MMS (Table 2), each representing their entire collection of BRFB.

The information provided in Europeana includes high-resolution, downloadable images and broad, primarily administrative, descriptions. Thus, Europeana emerges as a reliable starting point catalogue for directing towards museums hosting BRFB. It should be noted that out of the 12 European museums providing online access to their collections, which include BRFB, only two are aggregated in Europeana (KMV and MMS). Thus, only 16% of the total number of BRFB available for online consultation are findable in Europeana, which represents a statistically low 4% of the total number of BRFB discovered so far.

Examining the results of GA&C, a different picture emerges, denoting a different strategy in aggregating and indexing information. While the very specific term “ring base” did not yield any results, the keywords “bronze age terracotta” returned seven results, three of them being relevant and pointing to USA-based museums (MET, Brooklyn Museum and Glencairn Museum). Thus, it seems that Europeana follows information as provided by its aggregators, who prefer to use commonly used terms in the dedicated scientific literature; GA&C adopts a more “neutral” attitude, using generic terms and collaborating primarily with USA-based museums.

3.2. Museums’ Information on BRFB

Two aspects related to data provided by CH museums’ online catalogues hosting BRFB were explored: (a) provision of technical information on the organization/structure of the data, i.e., vocabularies, thesauri, schemata and data models, and (b) the content of the provided information, in relation to the first aim of this study. Regarding (a), only the Medelhavet museum in Sweden (MMS) provides explicit information on how its online catalogue is structured, being a component of a broader, nationwide initiative connecting several CH institutions in a single database system [46], CIDOC CRM based.

A total of 15 out of the 36 museums identified as hosting BRFB have online catalogues of their collections, providing together information on ca. a fifth of the BRFB uncovered so far. Out of these, only 10 museums disclose information on their provenance, most using the generic term “Cyprus,” and only four offer more information, such as locality of provenance (the toponym of the archaeological site). Two museums (BM and NMS) provide information on the archaeologist who excavated the BRFB. Only two museums (MMS and NMS) describe the archaeological context of the object’s provenance (floor of Tomb 3 in Enkomi and Tomb II, Asproyi, Kouklia Tombs, respectively).

Except for one, all museums deliver information on BRFB sizes, primarily maximum height, which is probably useful for their packaging and transport. There is a plethora of terms describing the materiality of BRFB, and often this description is provided together with information on the manufacturing technique, the most used terms being “terracotta” and “pottery”; some that they were “handmade” and “painted”, while a single museum (the Louvre) provides more extensive manufacturing details. Albeit of limited value for cultural-historical research, a strong motivation for museums to give priority to this kind of information is probably related to their identification, following ICOM’s recommendations, as set by Getty Research Institute’s Object ID, when dealing with the illicit trafficking of cultural goods [56].

Many of the BRFB museums’ descriptions mention their relation to base-ring ware (as their title explicitly mentions, see Table 2). However, none of these descriptions provide any link or factual data on any scientific analyses proving this statement. Moreover, an extensive online platform of scientific research on archaeological Levantine pottery [57] provides information on Base Ring Ware, deriving from various heritage science methods applied to 64 items of various ceramic vessel types [58], but not on any BRFB, or more generally, any Cypriot Late Bronze Age terracotta figurine. Despite the clear statement in one of the most extensive studies on BRFB [15], mentioning that “...Though there are resemblances with the ‘Base-ring’ ware, however, this fabric stands by itself, as in the case of other figurines of the LC period...” [15], p. 4, a more recent PhD thesis discussing the BRFB in detail [14] affirms that “...the anthropomorphic and zoomorphic figurines produced on the island during this period are mainly of the BR ware ...” [14], p. 72, without providing any petrographic, chemical or factual evidence based on direct scientific investigations on the BRFB to support this statement.

All museums have entries describing the culture/period of the BRFB as Late Bronze Age or Late Cypriot II, and the period as between 1450–1200 B.C.E.; the information is

provided in various formats, some using acronyms (e.g., L.C. II, 13th century B.C.E), others using numbers, positive or negative. The problems related to a formal description of the relation to archaeological cultures, time and space was discussed elsewhere [59–62]. Suffice to say, there is often an intercalation of concepts between chronological time periodization and archaeological cultures; for example, “Late Bronze Age” is often used to describe either one or the other.

The museums’ category “description” provides the most detailed portrayals of the BRFB (cf. Table 2). These include information on what the object is, how it was made, from which materials and what its presumed use was in the past. Texts are often a mixture of descriptive information and symbolic interpretation, along with information on their materiality and production techniques (see also [63]).

Overall, a main pattern observed that indirectly influences the type and content of information provided by museums is that BRFB, some exhibited and some not, are described in a de-contextualized way, away from their original archaeological context, and re-contextualized as art object exhibits, emphasizing their appearance rather than their meaning and use in the past.

3.3. AI-Based Descriptions of BRFB

Within the theoretical framework summarized in Figures 1 and 2 and based on an extensive review of the archaeological literature focusing on BRFB (introduced in Section 1.2), Table 4 presents an assessment of the summary on the state-of-the-art on current archaeological research outcomes on BRFB as compiled by AI models and based on the summaries of descriptions of BRFB as they appear in museums catalogues, under the labels “detailed descriptions” (and similar, cf. Table 2). The information provided by the unstructured summary texts generated by the AI models was grouped into three categories: (a) general features description; (b) manufacturing techniques; and (c) socio-cultural interpretations of the BRFBs’ functions; these were compared with the current state-of-the-art as it appears in the published literature presented in Section 1.2.

As mentioned above in Section 2.5, the summary of the Grok text was closest to the current state-of-the-art on BRFB, and it reflects the entries in the museums’ online catalogues under “description”, as probably manually inserted by the various curators responsible for BRFB in their dedicated museum departments. Its main highlights are provided here: “... handmade, hollow ... nude women ... exaggerated sexual features and schematic designs ... prominent breasts, incised and often painted pubis triangles, flat-topped heads with large ears, pellet eyes, and elongated noses. Arms ... crossed under the chest or clenched at the sides, with incised and painted details (black, red, or reddish-brown) for hair, lips, necklaces, and anatomical zones. Crafted in parts, smoothed or shaved ... reflect skilled terracotta artistry. Associated with a Cypriot fertility cult, possibly linked to a goddess like Astarte ... sacred figures symbolizing fertility and protection ... Found in tombs and households ... devotional objects for worship or prayer, offering protective roles for the deceased or living ... toys ... ritualistic design emphasizes their symbolic and religious significance, blending local Cypriot traditions with Near Eastern influences ... “.

The above text can be divided into three parts: (a) depiction of the appearance of BRFB by their anatomical features and attire, (b) detail of manufacturing techniques, and (c) description of the possible socio-cultural role BRFB played in the past. Table 4 provides a comparison of each AI statement and the current state of research on BRFB.

Table 4. Assessment of AI-based descriptive summary of BRFB (statements placed in the center of the rows are aligned with current state-of-research).

AI-Based Statement	Current State-of-Research Resulting from Literature Review
(a) depiction statements	
Hollow	Not all figurines are hollow
Prominent breasts	Some pointed; overall, rather small sizes
	Flat-topped heads with large ears, pellet eyes, and elongated noses
	Exaggerated sexual features, incised and often painted pubis triangles
	Arms ... crossed under the chest or clenched at the sides
(b) manufacturing techniques	
	Schematic designs
	Crafted in parts, smoothed or shaved
	Incised...painted details (black, red, or reddish-brown) for hair, lips, necklaces...anatomical zones
Skilled terracotta artistry	Subjective statement, un-supported by facts
(c) socio-cultural interpretations of the BRFBs' functions	
Associated with a Cypriot fertility cult	Unsupported by archaeological context/iconology study
Possibly linked to a goddess like Astarte	None of the typical Astarte attributes appear on BRFB
Toys	Mentioned in one museum entry, unsupported by research
Ritualistic design	Generalized statement (which design? Which ritual?)
Symbolic and religious significance	There are no direct historical sources describing the religion in Cyprus during the Late Bronze Age
Blending local Cypriot traditions with Near Eastern influences	Statement primarily related to other types of figurines

Table 4 shows that while AI models largely deliver coherent summaries, aligned with and being as good as their source (museums' online catalogues), in the case of BRFB, the content of the entries provided by museum curators responsible for maintaining updated information on these online catalogues often include statements not supported by factual evidence, and thus are of little scientific value, primarily in what regards the interpretative aspects of BRFB (section [c] in Table 4). Since most museums follow ICOM's OBJECT ID data model, primarily aimed at helping combat the illicit trafficking of cultural goods, it is expected that such descriptions have only limited use in archaeological research.

To sum up, the main challenge of AI models is first to provide them access to museums' online catalogue content (their metadata not being a factor here), followed by an improvement in how such data is summarized, confined to factual descriptions, without adding wordings that may fit perhaps in a general-purpose narrative, but lack the required scientific integrity. However, AI models cannot create quality by themselves; the example of BRFB presented above showcases the importance of providing AI models access to research data and outcomes, which museums' online catalogues do not, and should not, given their different scopes. As presented above, the ECCCH and its mission exactly aim to fill this gap by gathering research data from elsewhere as well, and creating the digital commons, multi-layered Heritage Digital Twins, integrating documentation from a variety of sources and unified with the use of the Heritage Digital Twin Ontology (see below).

4. Towards a Paradigm Shift in CH Research—ECHOES' HDTO

Conducting synthetic research based on data accessible online as provided by dedicated CH platforms, such as Europeana or GA&C, and museums' online catalogues proves to be a challenging endeavor [63,64]. Studying the socio-cultural and economic role(s) BRFB played in the past, and in more general terms, other CH material culture

assets, requires intersecting pluri-disciplinary research paths. As per Figure 2, these include cultural anthropology, primarily exploring their archaeological context and bibliographic resources providing related explanations, iconology, exploring the social meaning, cultural significance and visual messages embedded into the BRFB and heritage science-based studies, looking into materiality, production modes and use of these objects.

As stated earlier, the European Commission launched an ambitious initiative to create a (digital) Cloud dedicated to Cultural Heritage Data, the project ECHOES being the main body to create its infrastructure, and provide its conceptual data model and access to advanced digital tools transforming the data available into new knowledge for a variety of CH communities. Ultimately, its success depends on the quality of data available.

The success of the ECCCH in achieving its mission (and consequently the quality of information generated by AI models) highly depends on the need to advance and adopt a paradigm shift in how research outcomes are made available, primarily related to data provenance (and in broader terms, the implementation of the FAIR data principles [49]). Within this context, ECHOES is developing concepts and tools (Figure 3) aimed at bridging the knowledge pyramid [65–67] and the data lifecycle and considering the intricacies of CH data [68–71].

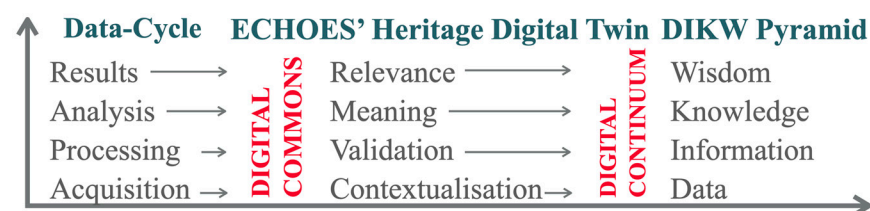


Figure 3. ECHOES' tools and methods bridging the data cycle and the knowledge pyramid.

These relate to two fundamental concepts: the data-cycle, addressed as digital commons and defined as “holistic social institutions for governing the (re)production of (digital) resources, created and/or maintained online and articulated through interrelated legal, socio-cultural, economic and institutional dimensions”, highlighting their nature as a joint, cross-disciplinary effort, while the progressive development of the knowledge pyramid is achieved by addressing it as a digital continuum effort, defined as “the ability to maintain digital information...in such a way that it will continue to be available, as needed, despite changes in digital technologies ... making sure that it is complete, available and usable”. Consequently, ECHOES adopted the definition of the Heritage Digital Twin (HDT), presented in [38,39] and applied in [41], as “the complex of digital information about a real-world heritage asset, with its tangible and intangible components, capturing the entirety of its space-time-culture identity and formally organized in a semantic framework, and described by the CRM—based ontology (HDTO)”.

The HDTO provides the semantic structure, helping to integrate data on a heritage asset originating from multiple sources and generated by different disciplines. It explicitly models the dynamic, socially conferred nature of heritage value, the provenance of digital knowledge production and the evolving relationship between real-world assets and their digital counterparts. This enables the systematic aggregation of multimodal data (3D models, scientific analyses, restoration records, narratives) into versioned, semantically coherent Digital Commons that capture the full space-time-culture identity of heritage assets. Going up the ladder of the data cycle and the knowledge pyramid (Figure 3), data provenance [72] is formally contextualized by (1) providing technical information on how it was created, the workflows that generated it and related paradata; (2) by formal description of the protocols of processing data, validating the recent generation of information

and (3) by formal description of passing on of historical information (or oral tradition) from one hand and valid source to another, to the degree possible.

The CIDOC-CRM-based HDTO specializes in the following epistemological areas and connects them into a functionally complete whole. Three main functionalities are important to highlight here:

- [a] How some specific items or traditions are defined to constitute a unit of cultural heritage, i.e., which current social groupings claim historically justified social or spiritual ties of whatever kind to one or more related heritage items, and which (typically wider) identifiable current social groupings explicitly value these items as cultural heritage and respect their specific local ties. This provides the definition of one identity—one HDT.

The above is implemented by the classes HC1 Heritage Entity and subclasses, HC10 Heritage Valuation, HC12 Heritage Declaration Event and their respective properties, as well as by related CRM concepts (Figure 4).

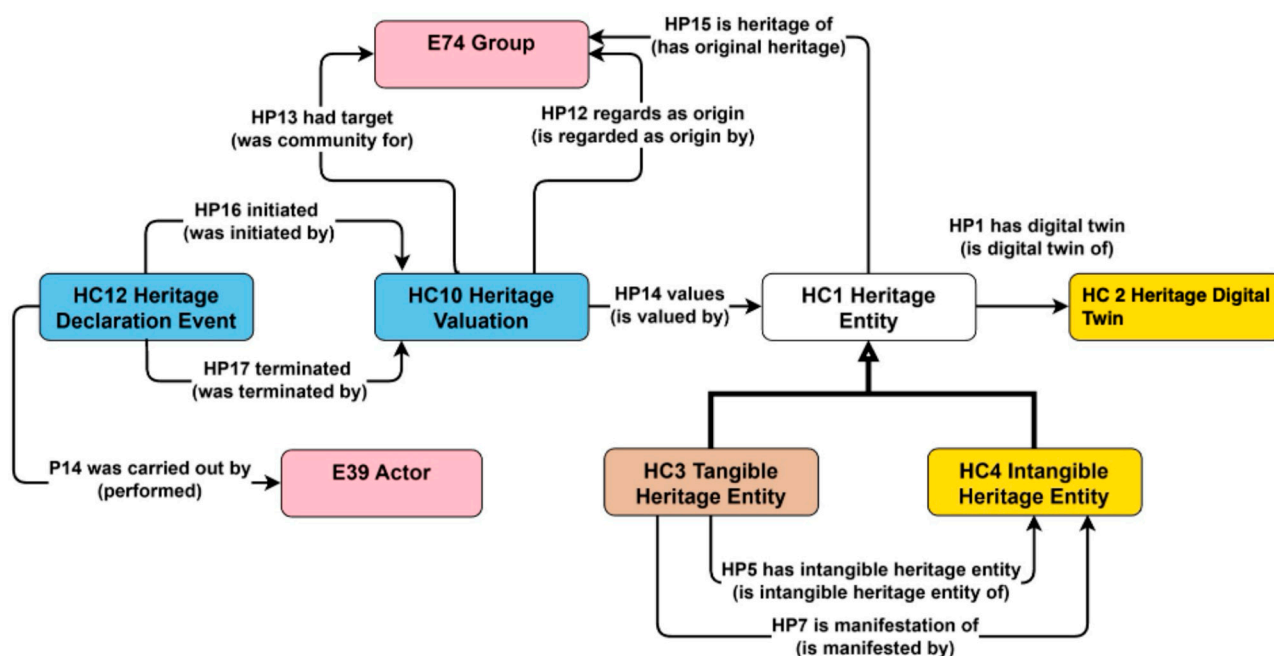


Figure 4. The declaration of an entity as a unit of cultural heritage.

- [b] The second function relates to how an HDT is defined and maintained by some organized collaborative framework, i.e., how the knowledge in the HDT is maintained, updated and kept up to date by the responsible consortium, caring for the authenticity, relevance and scientific quality of its content. The semantic model distinguishes between “volatile” and “persistent” digital content, among others, from [73,74] to connect the at times well-defined but changing content of the HDT with the citable scholarly publications and their provenance that make or had made it up [75,76]. It further foresees properties for explicating part–whole relations to HDTs of other heritage entity units and to potentially competing projects. However, the main purpose of this function is to systematically organize and monitor the completion of an HDT into a cumulative and comprehensive set of documentation of relevant disciplinary aspects. For that sake, it may also be combined with a more detailed workflow model that is adequate for scholarly collaboration. It can be considered as the administrative framework for eliciting or selecting the studies or documents with a specific disciplinary focus on the respective heritage entity.

This functionality is implemented by the classes HC13 Project, HC11 Digital Twin Maintenance (the up-date event), HC2 Heritage Digital Twin (subclass of HC14 Volatile Digital Object), HC16 Heritage Proposition Set (the persistent content parts, subclass of HC15 Persistent Digital Object) and their respective properties, in particular those to HC9 Study and crm:E31 Document, as well as to other related CRM-based concepts (Figure 5).

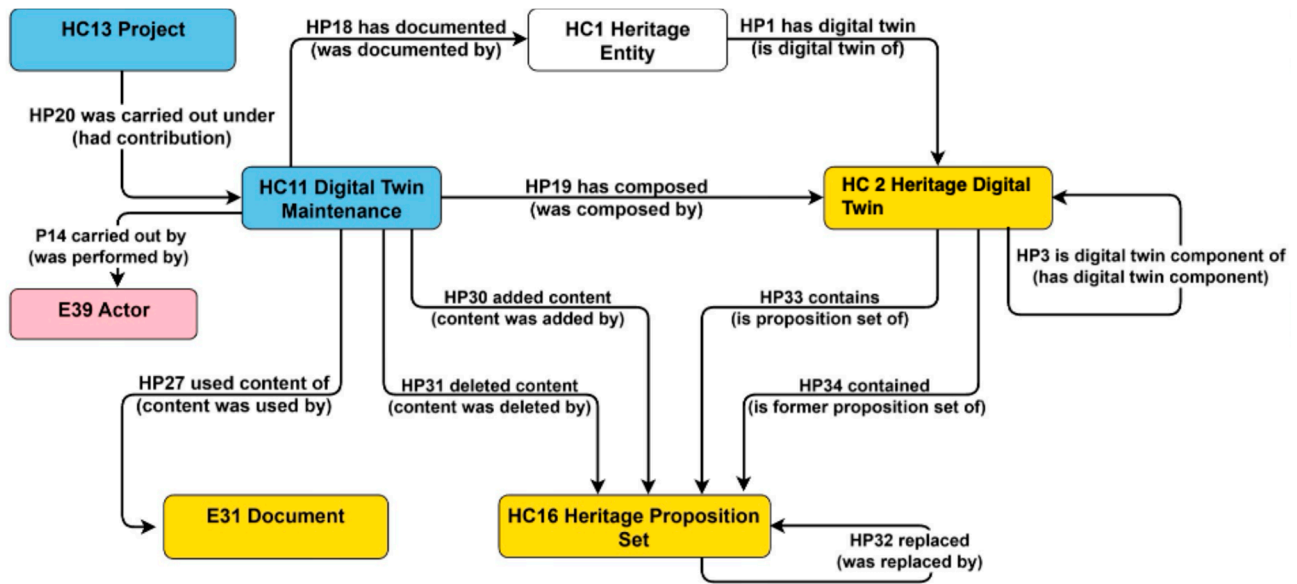


Figure 5. The maintenance of an HDT by an organized collaborative framework.

[c] The last function concerns the processes of creating studies and the representation of their findings about specific disciplinary aspects of a heritage entity or its parts, by ethnographic, archaeological or natural science methods, detailing the empirical-observational level, or by the analysis of historical sources and their authenticity. It further comprises cross-disciplinary studies and annotated literature. The studies may have been carried out or not on behalf of the specific consortium maintaining the HDT. A factual representation of the findings, together with metadata and the data provenance, should be provided in digital knowledge representation encoding to be embedded in the knowledge graph of a corresponding HC16 Heritage Proposition Set, and thus become globally accessible to digital processing in all detail. They should include primary digital visual or audio-visual representations with all their metadata. Beyond that, they should always be accompanied by a comprehensive, citable and open-access scholarly publication for a complete description of the context and interpretations, keeping in mind the dangers of format obsolescence.

This functionality is implemented by the classes HC9 Study, in particular explicating the disciplinary focus and part of the heritage entity investigated for understanding and managing the cross-disciplinary coverage of the HDT. The study, being either legacy or current, always results in a crm:E31 Document, regardless of format. By inheritance, the latter includes the classes HC5 Digital Representation and subclasses, using and specializing the CRM extension CRMdig [77]. Via inclusion in the knowledge graph, the data analysis process in a study is captured by a description of the reasoning, through the CRM argumentation model [34] and CRMsci [78], pairing between observations and their derivative statements in order to formally express the knowledge acquired through the analyses performed. The argumentation model also applies to the passing on of information (Figure 6).

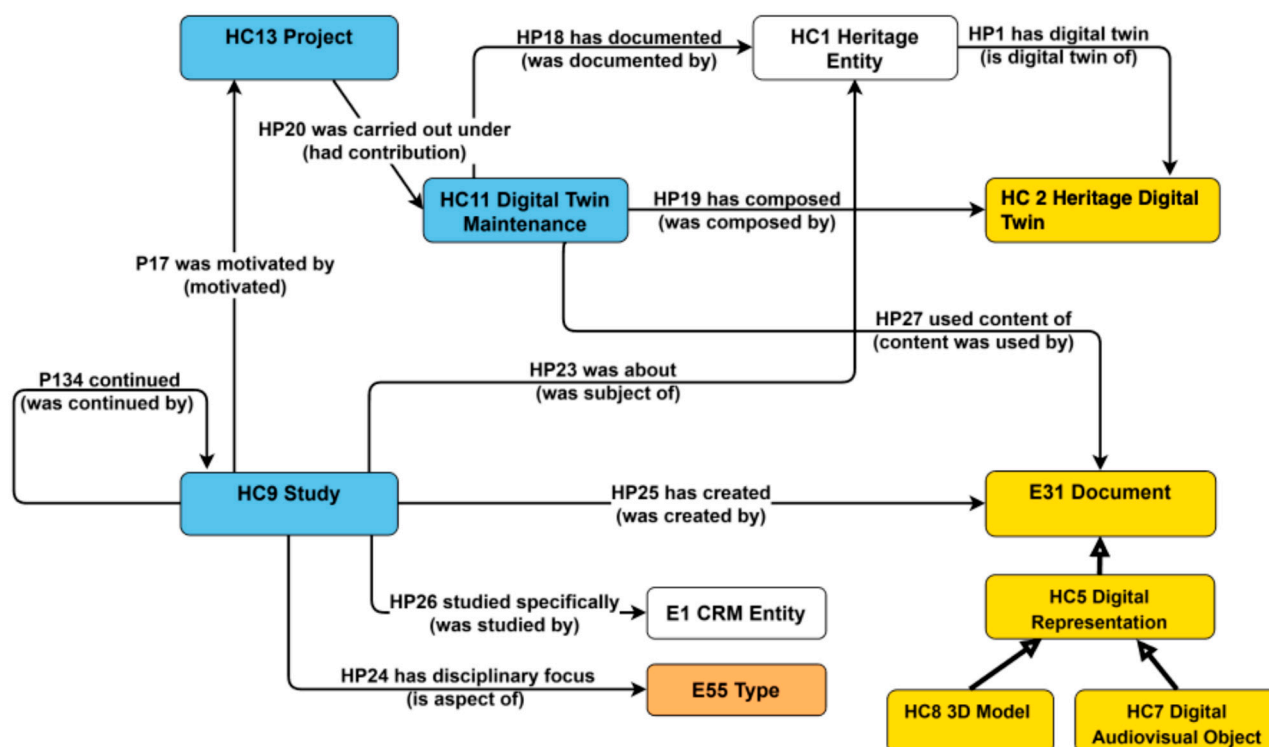


Figure 6. Studies and the representation of their findings about specific disciplinary aspects of a heritage entity or its parts.

Per the above functions, the HDTO is designed to enable the interested communities to overcome major shortcomings identified in this paper: (1) The lack of reliable provenance information of scientific findings and referred and passed-on information; (2) the lack of formally expressed contextual knowledge, rather than administrative data, about heritage entities; (3) the lack of complementary multi-disciplinary documentation; and (4) the lack of effective indexing of literature by its relation to a heritage entity rather than to its general library subject. It does so by providing a conceptual model for an IT environment to manage and monitor open collaborations between respective experts and communities across institutions, for continuously complementing and improving cross-disciplinary documentation and access to it for the needs of communities of use. The results of the research will be considered by these communities in order to assess their usefulness and relevance to create the sought wisdom. This is achievable by a formal representation of the relation between the research question, the methodology applied and the accountability of results, all aspects formally expressed in the HDTO and its related data model.

5. Summary and Conclusions

Several sources of information were explored to gather data for synthetic research on BRFB, with an emphasis on data provided by museums and CH's large-scale digital data-gathering platforms. Exploring several keyword searches, Europeana is a reliable entry point to a catalogue of millions of objects, described through the EDM model and complemented with audio-visual documentation material. The fact that BRFB has a presence in Europeana demonstrates its universality and its role as a massive catalogue of European CH assets' descriptions, and, as such, a good starting point for further research.

A Google Scholar search for articles and books, cross-checked with publication lists provided by museums, may lead to more available online information on BRFB. However, in the case of BRFB, most of the domain literature is available only as hard copies available for commercial purchase, in university libraries or through academic subscriptions.

The study has shown that in the case of BRFB, information provided by museums hosting them cannot serve as a base for their scientific, synthetic study. This case further exemplifies the complex situation in which heritage assets originating from a single country/culture are administered by many museums spread over a wide geographic area and across different socio-cultural contexts. This leads to a plethora of descriptive terms, often applying conceptually different approaches in presenting information on the same type of assets. The structure of information provided by museum entries is easily mappable into the ECHOES data model, as recently presented in [55], but it is not sufficient to gather information to perform synthetic research on BRFB. Often, this information is referenced in catalogues of their own collections, with only a few of them being digitized, and fewer available for online consultation.

The AI-generated descriptive texts on the BRFB are only partially correct and often mix evidence with unverified hypotheses and assumptions based on a limited number of available online sources, which are often not scientifically reviewed. For example, Wikidata, the open knowledge base on which Wikipedia and similar projects are built, provides information on a single BRFB extracted from the Louvre online catalogue, but vaguely described as “Naked woman holding her breasts”. Consequently, an example of pseudo-scientific information available online related to BRFB links the shape of figurines with ancient astronomical writing [79], further exemplifying the potential negative contribution of such information to AI-generated texts.

Since AI tools rely on access to large datasets for consolidating, strengthening and defining statements, there is an imperative need to have access to available online information that is grounded in scientific foundations. This could pave the way to use future AI models with RAG (Retrieval-Augmented Generation [80]) support and train AI agents on large-scale scientific data based on the FAIR principles, as set among the goals of the ECCCH.

The success of the ECCCH is therefore directly related to the quality of data available for further processing in a variety of applications. Access to raw, processed and post-processed data, along with an explicit description of their provenance, the workflows applied and the reasoning processes involved, is fundamental for achieving the goals of creating a virtual, collaborative environment for CH. While the ECHOES’ data model and the related HDTO ontology [69] have the expected complexity to properly address the requirements for enabling gathering and managing CH digital commons and ensuring their digital continuum, as required by the *ex-ante* Report on a European Collaborative Cloud for Cultural Heritage [1], opening access to high-quality data remains a task to be fulfilled by the research communities, which, in turn, necessitates the transformation of the CH research domain from a competitive one to a collaborative one.

Finally, looking at the three aims of the research presented here, namely to [a] explore the suitability of BRFB descriptions provided by museums’ online catalogues as the basis for synthetic research on BRFB aimed to reconstruct their past socio-economic and cultural roles; [b] examine the accuracy of summaries produced by freely available commercial AI models, based on information on BRFB provided by CH museums; and [c] verify the readiness of the ECHOES’ ontology to capture the entirety of museums’ catalogue metadata on BRFB, the results have shown that [a’] online museum catalogues, largely based on the Object ID documentation standard, provide limited information that is useful in conducting archaeological synthetic research on BRFB; [b’] while the features description and manufacturing techniques of BRFB are largely accurate (with a few over-generalizations), none of the six interpretative statements, the most important of which consider the initial aim of conducting synthetic research, are accurate (see Table 4); and [c’] the HDTO, based on the CIDOC-CRM ontology, covers the entirety of the museums’ catalogued metadata in a comprehensive way.

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