

## Original Study

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# Curating Archaeological Knowledge in the Digital Continuum: from Practice to Infrastructure

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**Abstract:** As a “grand challenge” for digital archaeology, I propose the adoption of programmatic research to meet the challenges of archaeological curation in the digital continuum, contingent on curation-enabled global digital infrastructures, and on contested regimes of archaeological knowledge production and meaning making. My motivation stems from an interest in the sociotechnical practices of archaeology, viewed as purposeful activities centred on material traces of past human presence. This is exemplified in contemporary practices of interpretation “at the trowel’s edge”, in epistemological reflexivity and in pluralization of archaeological knowledge. Adopting a practice-centred approach, I examine how the archaeological record is constructed and curated through archaeological activity “from the field to the screen” in a variety of archaeological situations. I call attention to Çatalhöyük as a salient case study illustrating the ubiquity of digital curation practices in experimental, well-resourced and purposefully theorized archaeological fieldwork, and I propose a conceptualization of digital curation as a pervasive, epistemic-pragmatic activity extending across the lifecycle of archaeological work. To address these challenges, I introduce a medium-term research agenda that speaks both to epistemic questions of theory in archaeology and information science, and to pragmatic concerns of digital curation, its methods, and application in archaeology. The agenda I propose calls for multidisciplinary, multi-team, multiyear research of a programmatic nature, aiming to re-examine archaeological ontology, to conduct focused research on pervasive archaeological research practices and methods, and to design and develop curation functionalities coupled with existing pervasive digital infrastructures used by archaeologists. It has a potential value in helping to establish an epistemologically coherent framework for the interdisciplinary field of archaeological curation, in aligning archaeological ontologies work with practice-based, agency-oriented and participatory theorizations of material culture, and in matching the specification and design of archaeological digital infrastructures with the increasingly globalized, ubiquitous and pervasive digital information environment and the multiple contexts of contemporary meaning-making in archaeology.

**Keywords:** archaeological curation; digital continuum; social studies of practice; digital infrastructures; ontologies

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# 1 Introduction

Thirty years ago, in his diagnosis of an “archaeology at the crossroads”, Bruce Trigger had posed the question: “Is archaeology in serious trouble, or does it stand on the threshold of brilliant new accomplishments?” [1]. While the original dilemma between a neo-evolutionist, systems-theoretical, nomothetic science of archaeology on the one hand and a post-processual, historical, idiographic humanity on the other seems to have merely morphed to a new mutation today, archaeology appears to be once again at a crossroads, shaped by the interaction between its evolving theoretical and epistemological horizons, and the sociotechnical infrastructures informing its increasingly digital practices.

Trigger’s question resonates with the existential question voiced by Jeremy Huggett [2] in his recent call to consider if the field of digital archaeology, rising from the ashes of archaeological computing, is able to take the form of an “archaeological information science” [3] with its own intellectual core – a theoretical and epistemological corpus that lays claim to disciplinary autonomy and maturity. Huggett suggests a good criterion consists in the ability of digital archaeology to articulate a “grand challenge”, which could take the form of a cohesive research problem and an approach capable of “getting us to rethink archaeology”. This should be challenging enough to require a mobilization of a research programme rather than a single project, and an interdisciplinary, likely multi-organizational and international effort, and tangible enough to be the focus of pragmatic, action-oriented research activity with a foreseeable horizon for success. The textbook example of a grand challenge he cites is the decoding of the human genome: a twenty year effort that, it should be noted, managed to transform fundamentally the status of research fields such as molecular biology and genetics, to introduce a new paradigm for the future of health care, and to spawn entirely original topics of inquiry in the social sciences and the humanities.

Seeking an “archaeology equivalent” as momentous to future human experience as the human genome may be an unattainable and, possibly also, inadvisable objective. Huggett’s quest for the “soul” of digital archaeology is, *mutatis mutandis*, as pragmatically consequential as it is ethically salient at a time when material cultural heritage – in other words, the construction of the material record of humanity – becomes increasingly enmeshed with agendas and practices of cultural contestation and appropriation, and increasingly mediated by pervasive digital infrastructures in an interconnected, globalized world. From the repatriation of First Nations artefacts and human remains to the restitution of the Parthenon marbles, and from the symbiosis of archaeological fieldwork with global cultures to an understanding of the symbolic agency of things on human cognition, archaeologists are called to respond to epistemic and pragmatic challenges transcending the formal boundaries of traditional archaeological research. These include questions of community engagement, interpretation and meaning-making of the archaeological record [4, 5] which, at a time when digital technologies become ubiquitous, may take the form of a “digital public archaeology” [6, cf. 7], but also vexing issues of preservation, management and appropriation of archaeological resources at a time of increasing scarcity of public funds available for archaeological research and growing privatization of fieldwork in the form of contract, or commercial, archaeology.

These considerations may appear foreign in the context of a dominant brand of digital archaeology driven by funding agendas and disciplinary norms dictated, in turn, by technological rather than archaeological imperatives – a fact noted by Huggett pointedly with regard to initiatives such as the EPOCH Research Agenda [8]. In fact, questions of huge impact to archaeological theory and practice during the last half century, stemming from post-colonial, feminist, indigenous, Marxist, and hermeneutic approaches, appear to be peripheral in the literature, subject-matter, and interests of digital archaeology. While more systematic research is needed to confirm this view, it seems to be supported by a preliminary word frequency and keyword-in-context analysis I conducted on the full text of the 2011 proceedings of the major conference of the field, Computer Applications and Quantitative Methods in Archaeology [9], where terms related to such approaches are present in only one of forty four articles included, with this single article focusing on digital exhibition rather than archaeological research in the strict sense [10]. It is not accidental that digital archaeology is thus laid open to critiques of being technocratic, apolitical and indifferent to social and cultural concerns [11] and of relating poorly with “theoretical orientations currently found in archaeology” [3], giving rise to an “anxiety discourse” that considers it “under-theorised” and casts doubts on the value of its broader theoretical import [2].

Yet, theoretical questions of social and cultural relevance have been seminal to the birth of archaeological computing, and, in fact, still remain a salient strand of contemporary digital archaeology, as concerns of intellectual property, professional incentives, cultural appropriation and ethics inherent to its advocacy of open access to archaeological data demonstrate. As digital methods, infrastructures, and tools are rapidly enmeshed in mainstream archaeological research and communication practice, and as digital competencies become commonplace, the “digital” in digital archaeology is destined to become extinct, transparent, and invisible, in the same way as it has been already in such fields as high energy physics or molecular biology. Therefore, a grand challenge for digital archaeology simply could not have as its yardstick a criterion of making digital archaeology distinct and autonomous, heeding Marcos Llobera’s call for an “archaeological information science” [3], or, to paraphrase David Clarke’s iconic turn of phrase, merely insisting that “digital archaeology is digital archaeology is digital archaeology” [12], but by doing archaeology digitally it should seek, instead, to make a difference to the broader epistemic and pragmatic contexts of archaeological work.

The call to propose particular “grand challenges” to digital archaeology, advanced in a special session of the Computer Applications and Quantitative Methods in Archaeology conference in April 2014 in Paris, and further pursued in the CAA 2015 conference in Siena, has already elicited diverse responses. Some of the responses addressing substantive questions of archaeological research deemed to span across areas of archaeology and to be amenable to the use of digital methods, tools and services in archaeological work. The process finds a counterpart in the initiative spearheaded by the director of the Digital Archaeological Record (tDAR) Keith Kintigh and his co-workers in the United States, a crowdsourced synthesis on grand challenges in archaeology reporting on the results of a large scale campaign, a workshop and a web survey involving a large number of archaeologists, most of them senior US researchers [13]. Most proposals reported in that study focus on important substantive questions of archaeological research that cut across particular research topics, under the following synthetic themes: emergence, communities and complexity; resilience, persistence, and collapse; movement, mobility, and migration; cognition, behaviour, and identity; and, human-environment interactions. Yet, as reported by Kintigh and co-authors, a number of respondents to their study identify an alternative grand challenge for archaeological research: “inadequate access to data and the need for more comparative and synthetic research” [13]. Instead of focusing on substantive issues of archaeological research, these respondents foreground an issue that hinges on the sociotechnical infrastructure [14, 15] of archaeology: the formation, access and use of archaeological “data”, and the promise of digital tools and services operating on such data for future research.

Similarly, the motivation for my response to Huggett’s challenge has been an interest in interactions between the increasingly digital sociotechnical infrastructure of archaeology and archaeological practices, viewed as purposeful activities centred on material traces of past human presence and spanning the domains of academic research, management of cultural resources, and public interpretation and appropriation. The curation of archaeological collections – artefacts, excavation records, photographs, laboratory notes and, increasingly, digital data emerging from archaeological research – is recognized as an important part of the work of archaeologists, and as a rising worldwide concern regarding the preservation of the archaeological record. Criteria, conditions, methods and procedures ensuring adequate archaeological curation “from the field to the repository” are included in the canonical knowledge presented in textbooks on field archaeology, and are part of regulatory and legislative efforts such as NAGPRA and the 1979 Archaeological Resources Protection Act in the United States, as well as accreditation programs to encourage initiatives at the level of primary research projects [16–20]. Nevertheless, a global curation crisis has been identified in archaeology as early as the 1980s, linked with the increasing range and magnitude of partially recorded, disorganized, and fragile archaeological collections and documentation archives produced by research projects, including those operating in an increasingly common commercial archaeology regime, and with the lack of effective and cost-efficient policies and mechanisms to ensure the long-term preservation and future usability of archaeological research archives [21–23].

Digital technology has created new problems and opportunities for the curation of archaeological archives, especially linked to the introduction of information systems to ensure the recording, storage,

preservation and access to archaeological research data, as well as the more recent emergence of sustainability models and secondary depositories which may accept custodial responsibility for future digital preservation and access of primary research data collections, such as the Archaeology Data Service (ADS) in the United Kingdom and tDAR in the United States [24–28]. The value of digital repositories such as ADS or tDAR, and more generally of digital infrastructures dedicated to the long term preservation and access to archaeological research data and documents is as exasperatingly ignored by so many archaeological projects and practitioners as well-understood and convincingly argued by experts in the field [26, 28–30]. As argued recently by Kintigh et al., the proliferation of archaeological work in the context of “publicly funded compliance projects”, leading to a “tsunami of reports of data” that remain unpublished and difficult to find despite their potential research value, makes a powerful point for the urgency of the situation. To secure the preservation and leverage the value of such data for the benefit of synthetic and comparative archaeological research, these authors recommend investments in a centralized digital infrastructure – an “archaeological synthesis center” – which could help aggregate, integrate and spearhead research on archaeological information resources across projects, regions and subfields, and could make them amenable to cross-disciplinary reuse. In their view, such infrastructures should “take into account the complete knowledge creation process, which includes research planning, data collection and organization, quality assurance, metadata creation [...], preservation [...], data discovery, data integration, and data analysis and visualization” [31].

While recognizing the continuing value of strategies of curating the archaeological record based on deposition to centralized, secondary digital archives or repositories, I advocate here a radically different direction. In short, I argue that the epistemological premises and pragmatic consequences of emergent archaeological practices, combined with the growing role of global and ubiquitous digital infrastructures on archaeological research activity, redefine the question of where archaeological curation is, which is its object, how it is enacted, and what kinds of technological “mediational artefacts” – not just hardware devices but also methods and procedures, digital services and tools – it entails [32, 33]. Adopting a practice-centred perspective [34–36] to understanding archaeological curation, I look at examples of how the archaeological record is constructed and curated through archaeological activity “from the field to the screen” (taking into account approaches and ideas stemming from Web 2.0, participatory, and open archaeology), in order to establish the magnitude and particularity of problems faced in the curation of archaeological curation in a variety of contexts; then, I examine a case study of a high profile, well-resourced, and purposefully open to experimentation archaeological fieldwork project, in order to identify how digital technology may, in such circumstances, spur new practices and bring to the fore new challenges for the digital curation of the archaeological record; subsequently, I introduce a theorization of digital curation as pervasive epistemic-pragmatic activity, aiming to situate discussion of archaeological record management in the context of contemporary debates in archival science and digital curation; and, finally, on this basis I advance a medium-term research agenda that speaks both to epistemic questions of theory and epistemology of archaeological and archival work, and to pragmatic concerns of digital curation, its methods, and application in archaeology.

## 2 Constructing and curating the archaeological record

Archaeological excavation has been famously recognized as an “unrepeatable experiment” in which an archaeological site, viewed as a “document”, is “destroyed by the very process that enables us to read it” [37]. Yet “reading” the archaeological record is not a passive process. As noted by Gary Lock, excavation is an activity where recording overlaps with interpretation:

The process of excavating and recording an archaeological site is a curious mixture of intuition, interpretation, and pseudo-scientific rigour. Ideally, the end result of the process is an archive comprising written, drawn, and photographic representations of the removed physical features within the ground, the stratigraphical relationships between these features and actual samples, artefacts and ecofacts obtained from within them. The justification for such ‘preservation by record’ is that the archive is accessible for analysis, interpretation and future reinterpretation. [38]

The notion of the archaeological record encapsulates diverse potential meanings, which may be subsumed under two alternatives: firstly, as the totality of the material remains of past cultures found by archaeologists through survey or excavation, and, secondly, as the documentary archive derived through a recording process from these material remains. These two conceptualizations hark back to different origins: the former to the *fossil* record as defined by palaeontologists, presupposing a natural, objective process of formation, and the latter to the *historical* record, constructed as a social object by means of a structural, symbolic, or contextual process of representation [39, 40]. Yet these conceptions of archaeological record are not unrelated to each other. The *physical* record of material remains occupies the empirical domain of archaeology when its parts are found, excavated, individualized and selected, and the *textual* (in the broadest sense, including visual documentation) record is constructed by way of representation, transformation and interpretation of the physical record. The archaeological record as a documentary archive – the traces and inscriptions of archaeological facts made in the light of the prior knowledge, middle range theories, intuitions, and sense experiences of archaeologists as they conduct their research – is constructed at the same time as the archaeological record as material assemblage is irrevocably destroyed through excavation, gradually taking its place as evidence.

The record, viewed as the *curated* outcome of archaeological work – the selection and arrangement of assemblages and series of material remains from the soil, the descriptions of archaeological features and finds, the drawings, photographs and other representations of the archaeologists' impression of the site, and their recorded conjectures, ideas and questions – is all that remains to connect the physicality of the original site as it was created through deposition, and its constitution as an epistemic object, i.e., one amenable to knowledge work. The documentary archives representing the archaeological record exist as *matters of fact*, standing for the material remains of past human activity when they are transformed from “brute facts” into “institutional facts” [41, 42], or “from natural features into cultural objects” [40], by means of archaeological recording, description, and interpretation embodying the agency of archaeological work. They also become *matters of concern*, when “they give way to their complicated entanglements” [43] in the diachronic practices of archaeology, viewed both as intellectual inquiry consequential to contemporary issues, and as custodianship of a hybrid material/symbolic resource with social, cultural and economic value.

As synthetic research based on assessing a broad base of archaeological and other contextual (historical, geographic, anthropological, etc.) evidence rises in importance, and as archaeologists return to the study of particular archaeological sites, cultures and phenomena, making sense of archaeological archives, datasets and related materials that are the outcome of past archaeological work becomes a priority. In fact, studies of such archives demonstrate quite clearly the primacy of interpretation in shaping the nature of the archaeological record. For example, an analysis of the “orphaned” archaeological collection and archive of the Market Street Chinatown excavation in downtown San José, California [44], has shown how the ethnic affiliation of ‘Chinese’, ‘American’, ‘Euro-American’ and ‘Spanish’ assigned by excavators to individual archaeological features at the time of excavation on the sole basis of the provenance of objects found were in fact affirmations of contemporary cultural stereotypes, and how subsequent re-cataloguing and curation led to undermining and changing many of the original identifications. The identification of ethnic affiliation stands for a complex argument on artefact provenance, value, and use, which, in this case, is obscured in the original excavation records. In fact, legacy archaeological field records are full of such implicit cultural identifications, typically reduced to metadata without qualification, while in fact they hide conditional on contextual, and often complex, argumentation. As shown in this example, curation of the documentation of orphaned, under-reported and under-analyzed archaeological collections amounts not merely to a custodial process but to an epistemic endeavour inseparable from scholarly research. It has been aptly claimed that “attention to the process of curation highlights the materiality of archaeology [...] as a shared foundation of both excavation- and collections-based research” [44].

Archaeology developed its methodological principles of technology, typology, and stratigraphy as early as the late 18th century, allowing “the remains of the past to be organised into an ordered system by means of verifiable procedures of collection and classification” [45, 46]. It was concerned to show how “the

study of material remains from the past, and the conditions of their deposition and subsequent history [is not only about] associations of moveable artefacts and immovable features in their archaeological context [...] of space and time [but ...] also about the people behind the objects: their creators and users” [47]. Historically, its practice depended equally on fieldwork, and on the study of museum collections and corpora of collected artefacts. Classical archaeology, in particular, remains to date an idiographic, historical discipline, using philological methods of written source interpretation to elucidate problems emerging from material things, and sharing methods of art history for morphological and aesthetic analysis of object form [48]. Artefact analysis, from formal and material examination to comparison with other objects, definition of socio-cultural context, consideration of provenancial and contemporary meaning, and interpretation [49] is typical of museum-based curation in Classical archaeology:

Quite frequently a scholar might find a fragment of a sculpture or vase in one museum that joins to a similar piece in another museum. [...] The same Archaic fragment is also part of several distributed assemblages of objects. For example, someone interested in the works of Sophilos would wish to consult all of the 91 works attributed to or signed by that artist [...] One might also be interested in studying the other vases and vase fragments that, like our Sophilos dinos, were found at the great Archaic Greek trading post, at Naucratis, in Egypt [50].

The process of a knowledge-laden activity illustrated by this example is a salient dimension of curatorial work; in fact, curating prior knowledge on objects and their contexts bridges the realm of scholarly research with that of documentation and collections management. As noted by cultural heritage informatics scholar Jennifer Trant, museum curation, context-dependent artefact meanings manifest themselves “through repeated re-documentation whenever a work is included in an exhibition, published in a book or article, or hung in a gallery, or otherwise engaged in the service of the museum’s educational or research mission” [51], pointing at how the construction of curatorial knowledge is enmeshed in situated, mundane, materially grounded practices of information.

In the same vein, considering the material-discursive practice of archaeological fieldwork, applied linguist Charles Goodwin notes that:

[...] a purely symbolic understanding of work relevant categories, such as “disturbance” or “post mold” [...] in no way provides a working archaeologist with the skills and professional vision required to competently locate disturbances with their rich physical variety — material traces of plows, burrowing rodents, etc. — in the actual dirt that it is her job to excavate [52].

Christopher Witmore expands this notion of localized, situated context by framing the relationship between the primary archaeological “data” and the meaning-laden tangible manifestations of archaeological knowledge – logbooks, catalogue text, plans, maps, illustrations – in terms of a mediation by multiple sociotechnical fields of activity, “encompass[ing] everything from funding bodies, sociopolitical alliances, media and materialities [...] things (our tapes, trowels, theodolites, media, etc.), too, have a stake in our nonlinear and interconnected paths of knowledge production” [53]. For Lambros Malafouris, “the trowel, more than a tool for digging, becomes a boundary artefact that inhabits simultaneously the realms of ‘pragmatic and epistemic action’” [54]. Llobera concludes that all such mediators of documenting the archaeological record, the “tangible pieces of information or ‘reasoning artefacts’”, are essential for the construction of archaeological knowledge [3]. A salient conclusion drawn from these insights is that, to make sense of the archaeological record, digitally or otherwise, we need to account for how the archaeologists’ “environmentally coupled gestures bring together in a single action package relevant categories and the actual things being categorized” [52] – in other words, to bring about a record of the actual epistemic and embodied encounter of the excavation team with the site in practice.

On the other hand, in his theorization of “archaeological constructs”, Jean-Claude Gardin demonstrated the centrality of processes of representation in the formation of the archaeological record and the construction of archaeological knowledge [55]. Gardin differentiated sharply between two kinds of archaeological works: “compilations” – for example, catalogues of finds, or excavation reports – concerned with material remains of the past and their attributes, and “explanations” – for example, synthetic monographs and interpretive

studies – concerned with ancient societies, their history and mode of life. After an early period dedicated to the definition of descriptive codes and representation languages for different classes of archaeological materials (i.e., to compilations), Gardin shifted his attention to the development of a method for the formal representation of archaeological reasoning (i.e., to explanations). His “practical epistemology”, the pragmatic imperative underlying his work, led him to question the traditional narrative form of archaeological publication and to advance the virtues of an alternative, “logicist” model of publication based on the “condensation” of archaeological discourse into a schematised sequence of inferences between logical propositions, organically connected with supporting archaeological data [56, 57].

The development of a logicist model of archaeological publication by Gardin finds a counterpart in the launch in 1996 of *Internet Archaeology* [58, 59], an online journal seeking to promote an enhanced model of presenting archaeological argument by supporting the direct manipulation and summarisation of data, the integration of spatial, chronological and typological visualizations and models, and the formal presentation of “arguments presented in papers [...] enhanced with ‘live’ views of data deposited in research archives, and subjected to a far greater degree of peer review” [60]. Julian Richards, its editor-in-chief, envisaged the journal as a means of serving “preservation by record” of archaeological evidence destroyed through excavation or decay, and intellectual access through different ways of reading and searching [61], employing generic (e.g., network graph, cross-tabulation and statistical summarization, mapping) and archaeology-specific (e.g., stratigraphic matrix) digital tools. Gardin, on the other hand, experimented with re-expressing the textual content of an archaeological publication into “a table containing all ... propositions that have explicit antecedents in the text (descriptions, analogies, supposedly established facts), then a diagram” [62], seeking to provide a succinct, and more amenable to quick consultation, alternative to narrative archaeological publication. As I argued recently, the possibility of integrating the argumentation structure of an archaeological publication with circumstantial and descriptive data, methodological principles adopted and results, as prescribed by the “Scientific Constructs and Data” (SCD) format proposed by Gardin and ethnoarchaeologist Valentine Roux [56, 63], “goes beyond [data publication] to acknowledge the interdependence between data constitution on the one hand, and scholarly argumentation on the other, and thus, implicitly, the futility of attempting to publish one in separation from the other” [57]. In view of the possibilities opened by approaches such as SCD and *Internet Archaeology*, advocacy for mere data publication in the field of digital scholarship seems, in fact, to be a retrogression, obscuring the theory-laden nature of archaeological data [57, cf. 64].

Despite differences in the nature of questions asked, methods used, epistemological premises, and rhetorical genres, all manifestations of archaeological knowledge hinge, primarily, on syllogisms made of material things, found in fieldwork or “re-excavated” in archives and museum collections, and on observations regarding their context; that is, not just the archaeological context of deposition and discovery, but also the epistemic context of their cultural biographies [65, 66]. Therefore, active curation of the archaeological record in the broader sense, viewed as being part of the knowledge-laden work of archaeologists and custodians of archaeological collections, is justified on both pragmatic (mainly evidential) and ethical grounds. In fact, in a recent interview-based qualitative study on faculty values and needs related to scholarly work, communication, and collaboration, several archaeologists noted the usefulness of making excavation data available for further research, suggesting that “it is important to record and archive the data from an excavation – what is termed ‘curation’ in archaeology – so that other scholars can ‘resuscitate the excavation from all of the data’”, and pointing to the importance of organizing and providing access to “diverse unpublished data, including field notes, artifacts, photographs, log notes, and databases” for future archaeological research [67]. In their archaeological curation manual, Lynne Sullivan and Terry Childs also assert that “[a] well-made, well-documented and well-curated collection [...] can provide fodder for numerous research projects, even if it was made two generations ago and lacks material classes for information now routinely collected” [17]. On the other hand, as the collection of objects and documents emerging from each excavation project assumes the status of “an irreplaceable record of the past”, it is reasonable to consider its preservation in a reliable and usable state as a necessary condition for “conducting further research, interpreting the past and managing archaeological resources in informed

ways” [68]. That the archaeological record plays out into multiple narratives and interpretations of the past, it becomes *de rigueur* a site of socially and culturally salient contestation between identities, in the context of nationalist, post-colonial, and indigenous archaeologies [69–74].

### 3 Archaeological fieldwork as pervasive curation: a case study

While archaeologists have traditionally considered themselves as “both stewards of, and advocates for, the archaeological record” [72] – as trusted third parties, bestowed the authority to act on behalf of society for the benefit of archaeological heritage – in late twentieth century archaeology’s undisputed authority has been challenged, on one hand by the epistemological shift connected with the rise of constructivist, interpretive, and pluralizing approaches to archaeological knowledge [75–77], and, on the other, by postcolonial changes in legal and societal attitudes towards ownership of archaeological heritage. This has led to a rapprochement between professional and indigenous archaeologies in Canada, Australia and the United States [78–80]. As noted by Neal Ferris, director of Ontario’s Sustainable Archaeology Lab, archaeologists in North America find themselves increasingly in a position of fiduciary responsibility on aboriginal archaeological heritage towards native and descendant communities, hopefully leading to more inclusive archaeological practice based on a “reconstituted ownership over the record (i.e., less about things)”, a study of the past “more accommodating of multiple, potentially contradictory tellings”, and “a shift from a parasitic to a symbiotic relationship” between archaeologists and descendant communities [72].

The growing entanglement of archaeological research with social concerns tied to land management and its use in the context of urban and rescue archaeology, as well as the emergence of approaches aimed to engage meaningfully non-archaeologists in archaeological work in the context of public or community archaeology [7, 81–83], point to a situation whereby the archaeological record is increasingly shaped by a multiplicity of stakeholders beyond academic and professional archaeologists. By way of example, as Stephanie Moser and co-investigators report, their Community Archaeology project on the Red Sea coast of Egypt “goes far beyond [consultation with local communities], incorporating a range of strategies designed to facilitate the involvement of local people in the investigation and interpretation of the past” [4]. Advocating for a more democratic archaeological practice that is enforced by the “bureaucratic professional tendency” dominating rescue-driven, positivist archaeological research projects, Neil Faulkner argues in favour of an “archaeology from below [...] rooted in the community, open to volunteer contributions, organised in a non-exclusive, non-hierarchical way, and dedicated to a research agenda in which material, methods and interpretation are allowed to interact”, thus supporting the promise of plural, multi-theoretical, multi-methodological approaches [84].

Digital technology emerges as an important factor in these developments. Mark Lake, introducing the influential recent movement towards “open archaeology”, points at the “potentially profound implications for archaeology of the heady cocktail of internet and locational technologies” towards democratization not just in accessing archaeological knowledge, but also in establishing new modes of knowledge production in archaeology in the form of citizen science, listing Wikipedia, Google Maps mash-ups, and blogging as pertinent examples. In fact, he adds, “one might be tempted to ask whether Open Archaeology is anything other than Community Archaeology viewed through the lens of the internet” [85]. The external technological environment in which open archaeology thrives is thus marked by the affordances of ubiquitous, pervasive digital infrastructures associated with Web 2.0, social media, and cloud computing. Similarly, Colleen Morgan and Stuart Eve describe this “brave new world” in the following terms:

We blog in plain language, we make our photographs and our videos free to view, use and redistribute, we distribute calls to action and we discuss, argue and record our conversations using Twitter and Storify. Noisy, multilingual and multi-authored, and sadly often unarchivable or incompatible with traditional means of archaeological publication, there is so much colour and life in our digital village that it defies boundaries and descriptions [...] As digital archaeologists, we email each other, enter our data into databases, upload photographs and try to understand, organise and preserve our digital traces [86].

On the basis of this emerging situation of archaeological work in the digital continuum of pervasive media and infrastructures, as well as their experience with the commercial Prescott Street excavation in London, Morgan and Eve make an argument for a “DIY archaeology” reliant on multimedia, plain language, and highly accessible archaeological communication, as a means to an emancipatory digital archaeological practice identified in the antipodes of the typically opaque grey literature of archaeological reports. Web communication, in their view, opens possibilities for unanticipated interpretations of archaeological data, leveraging the “social, serendipity model for information discovery” [86]. Such a do-it-yourself archaeology seems already to be taking shape through the growing number of archaeological projects making use of Web 2.0 and social media capabilities [87], tapping on the promise of open sharing, peer review and reuse of archaeological data – a form of “data sharing as publishing” – afforded by the online networked environment [88].

Stuart Jeffrey also highlights the dramatic shift to emerging approaches in information gathering, management and sharing linked to social media, collaborative websites and user-generated content, and the promise they bring to break boundaries between professional and non-professional realms. This suggests that “a lot of archaeological debate, as well as content creation and sharing can now take place in environments that are open, dynamic and fluid” [89]. The danger of “a second Digital Dark Age” linked to the adoption of non-custodial, social media approaches to archaeological information gathering and dissemination, to which Jeffrey calls attention, rings true, and his warning “that enthusiasm for adopting new approaches should be tempered with some consideration of the longevity of the outputs” [89] is, also, sensible. Nevertheless, it is difficult to imagine that such a warning will have a major tempering effect on actual practice, as digital infrastructures and tools such as cloud computing, social media and mobile devices become increasingly ubiquitous and pervasive. In fact, the dozens of archaeological fieldwork projects providing Web access to reports, data and additional research-related information resources, as well as the rise of collaborative initiatives demonstrating the potentials of connecting archaeological resources using Semantic Web technologies, such as “Pelagios: Enable Linked Ancient Geodata in Open Systems” [90], point to a trend that is unlikely to be reversed.

As Fredrick Limp argues, two different approaches, tool kits, and structures are likely to co-exist and contribute usefully to the advancement of open, “disintermediated” access to and reuse of archaeological information in the future:

We can, perhaps, characterize the first as top-down, where large institutions with large data sets make them accessible—for example, a major museum or university providing easy Web-enabled access to data on sites or objects in its collection. The other is bottom-up, where individuals provide the content—for example, where users create linkages of many forms (classificatory, analytical, and the like) between these and other objects and identify previously unrecognized relationships. While at one level the two are quite different, the value of each effort is multiplied by the presence of the other. [91]

Producing archaeological data from the bottom-up or “in the wild” – i.e., outside the top-down discipline of a custodial, centrally designed and managed information system – brings forth particular challenges for *ex post facto* archaeological data digital preservation and access. This situation is typical of the people that Leif Isaksen and his co-workers, seeking to integrate semantically legacy excavation data from the Roman Port Networks Project of the British School at Rome, identify as “microproviders”: individual academic workers and creators of personal webpages, typically “having a single-purpose dataset that they are willing to contribute [with] often personal details or research” [92]. Investigators working with the Central and Western Anatolian Neolithic Working Group to integrate and publish twelve archaeological datasets using the Open Context web-based archaeological recording system note that most data contributed by archaeologists were in Microsoft Excel format rather than in a relational database. Data were often expressed without unique data identifiers, ambiguously as regards the absence of particular traits, using undocumented codes, in summary rather than item level form, and with inconsistencies in structure and terminology. Seeking to resolve these problems “required back-and-forth communication between data editors and data contributors [without which] documentation gaps would have likely gone unnoticed and unresolved” [88]. Similarly, the extensive US study on digital infrastructure needs in archaeology by Kintigh et al. identified the lack of necessary contextual information, “incommensurate systematics employed by

different investigators”, inconsistencies in scales of data measurement, and the inherent complexity of archaeological entities, as severe impediments to archaeological data reuse [31].

Yet the challenges posed by the pervasiveness of digital infrastructures, the multiple stakeholders of archaeological information, and the inseparability between data and interpretation in archaeology are not limited to the case of isolated researchers, but become enmeshed in larger archaeological projects as well. A longer discussion of a case study of field research practice may serve to illustrate how, with the proliferation of pervasive digital infrastructures and capabilities, the actual process of archaeological research and interpretation has become inextricably enmeshed with and is now inseparable from *curation*. For this purpose I chose to focus on the multiyear, multi-team excavation of Çatalhöyük, the 9,000 year old Neolithic settlement in the Konya plain of Turkey. While we are not amiss of projects providing salient new perspectives on the import of digital methods, tools and practices on archaeological work [cf. the many examples in 87, 93, 94], Çatalhöyük is unique in being an exceptionally well-resourced, high profile, multi-team, international project open to methodological experimentation, reflexivity, and purposeful theorization, which has engaged in the extensive use of networked, mobile and media technologies in all stages of the research lifecycle. In selecting this example as a case study, my premise has been that the seeds for understanding and addressing a *grand challenge* for digital archaeology are to be sought not in routinized mainstream practice, but in the fledgling, emergent, and experimental approaches illustrated by atypical projects such as the Çatalhöyük excavation.

The constructed, contextual nature of the archaeological record, and its intimate dependence on the practices of excavation, recording, and interpretation, have been in the centre of the approach developed since 1993 by the excavators of Çatalhöyük. The site had already become known since the 1960s from the excavations directed by James Mellaart [95], for its association with the ancient worship of a female deity, attracting the interest of feminist archaeologists, eco-feminists, Gaia theorists, and Mother Goddess worshippers [96]. The methodological approach introduced by post-processualist excavation leader Ian Hodder, was explicitly meant to embrace the principles of *reflexivity*, *contextuality*, *interactivity*, and *multivocality* [97]. The imperative of reflexivity was to be served by the wholesale adoption of a twelve-point plan: on site interaction through tours on site; negotiations of priorities between excavators and laboratory staff; breaking down barriers between different kinds of materials and analyses; fast feedback from laboratory analyses to the field; an integrated database; a diary supporting and documenting the process of interpretation; anthropologists looking at archaeological process, visual conventions, and local community impact; a web-based database to enable multivocality; hypertext and hypermedia to break down linear narrative; virtual reality connected to the database and supporting visualisation; and teams of diverse nationalities supporting different versions, or “windows”, of Çatalhöyük [98].

Hodder, and those who joined the large international team of excavators on the basis of these premises, espoused the use of multimedia and digital technologies in all aspects of archaeological work, from survey and excavation recording to interpretation and public communication [97, 99–101]. Digital technology was adopted as a means of accounting effectively for the diversity and complexity of the archaeological record, the entanglement between recording and interpretation, and a desirable balance between data formalization useful for effective information retrieval and free expression to capture the nuance and complexity of archaeological intuitions in the field. The archaeological record of Çatalhöyük was constructed dynamically *in situ* as the excavation progressed, through a combination of single-context database recording, copious on-site digital photography, live 3D modelling and visualisation of the excavation, GIS mapping, personal digital diaries and reflexive video recordings, using a combination of tablet computers, digital and analogue cameras, digital video recorders, and specialized 3D capture, modelling and georeferencing hardware and software. The multimedia, multi-genre material was recorded in a relational database, and published both in print and in a searchable, hyperlinked form [101–106]. This is currently evolving into an online “living archive [...] having its core contents ‘frozen’ upon completion of excavation activities, but made highly accessible for future analysis and interpretation, and annotation by its publication as Linked Open Data (LOD), presented in a sophisticated interface allowing complex queries and faceted browsing on spatial, temporal and thematic dimensions”. For this purpose, data from a relational database were transformed into graph data described by an RDFS/OWL ontology, allowing the representation, retrieval and traversal of data according to semantic relationships between things and people [107].

Field recording in the main, British-led Çatalhöyük sectors of the excavation was based from the outset on the *single-context* recording system first introduced by the Museum of London's Archaeology Unit to deal with the stratigraphically complex sites in urban archaeology, which are “less readily open to higher order interpretations at the immediate point of excavation” [101, 108]. The single context method utilizes pro-forma recording sheets, each for a specific *archaeological context*, defined as “any human or natural event that is represented in the archaeological record” [109], broken down into individual pieces of data, recorded as systematically as possible, and acting “as a prompt and *aide-memoire* for the recorder, but also as a system of data management by cross referencing many different elements of related data” [38]. Single-context unit sheets are supplemented by skeleton sheets, feature sheets, building sheets, and space sheets, in a hierarchical structure [110]. As the excavation progresses, archaeologists fill context sheets for both “positive” contexts, representing the deposition of material such as individual layers within the fill of a pit, and also as “negative” contexts representing spatial entities defined by the removal of material, such as a pit or posthole.

The combination of single-context recording with reflexive accounts of archaeological meaning-making and multi-sensorial, interactive, immersive representations of the day-to-day situation in the field, made possible by virtue of the wholesale adoption of digital technology in Çatalhöyük, signals a convergence with the earlier *feature-group* recording system, characteristic of traditional excavation practice before computers, and based on the production of “written descriptive passages, short notes and annotated sketches in day books and diaries” [38]. Feature-group recording required interpretation of what was being excavated from the very beginning, so that “a foundation trench [could] be recorded as part of a wall, the wall part of the defining elements of a room, the room part of a building, the building part of a land use block” [108]. On the other hand, documentation using context sheets is also “far from mechanical and objective, as interpretation is unavoidably involved in identifying contexts and establishing their extent and relationships” [38]. Unlike feature-group recording, however, adoption of the single-context system in Çatalhöyük shifts the focus of curation to the identification and description of atomic informational units of analysis representing archaeological contexts, to their embedding into a stratigraphic matrix [109], and to the distributed, interconnected, and recursive interpretations and re-interpretations of both individual contexts and their relationships. Identification of archaeological entities at the time of field recording is contingent on the middle range theories, shared interpretative and reasoning skills, and performative, how-to knowledge forming “the archaeological *habitus*” of the excavation team:

We call a certain type of hole in the ground a pit because, as archaeological practitioners, we have an agreed index of attributes that qualify a hole in the ground to be recorded as a pit, as opposed to a ditch or a foundation trench. We think we know, or that we know how to tell, where the edges of said pit are via our observations of relative differences in colour/texture/constituents and coarse components between infill and that through which it is cut. [108]

The process of categorization appears, therefore, to be an inextricable part of even the most fundamental aspects of excavation recording, such as naming. Like in history, in archaeological documentation “[m]ost of the facts we gather come dripping with ideas” [111]. This enmeshing of archaeological archives with identifications imbued with interpretation extends, even more so, in attempts to capture cultural, meaning-laden associations in the archaeological record.

The Çatalhöyük project has been emblematic in its attention to the active construction and curation of a contextual, reflexive and interactive record of the excavation, viewed both as object and as process, with future use in mind from the outset. Çatalhöyük excavator Ruth Tringham asserts that the “sustainability of our archaeological product, especially when born digital”, requires two conditions to be met: “that the data—the documents of our research—are “born archival” [...] and that the archive be usable, meaningful, and used” [112]. To meet these conditions, field recording, far from being seen as a mechanical task, is treated as inseparable from the categorization process and the cultural identification of particular archaeological entities in real time, the outcomes of which are made available for further curation as archaeologists work towards publication. The active construction of the archaeological record is deemed to be an essential part of the curation process, enabled by the linking, versioning and annotation capabilities of digital technology:

[I]t is necessary for reflexive approaches to develop methods for documenting the documentation process. There are numerous ways in which the records can be embedded within an outer layer of documentation. For example, databases and archives can be tagged with a history that describes changes made through time. Diaries can be written which describe the thought processes of the excavators and laboratory analysts. [113]

Personal diaries of members of the research team – both excavators and lab people – have been used since 1996 in Çatalhöyük, but fell into disuse until the introduction, in 2012, of new functionalities in the diaries database, allowing researchers to annotate posts with relevant unit, feature, space and building numbers, and to respond and comment on earlier posts. Further recently introduced features include a “Diary Entry of the Day”, and a section “to write about topics such as their interpretive process regarding specific units (e.g. hypothesis for how particular deposits were formed, questions that have arisen over the course of excavation), how multiple units and features relate to one another, and the reasoning behind their excavation strategies” [104]. The diaries are supplemented, since 2012, by “the daily sketch [...] a kind of visual diary [...] done by the excavators, drawing and writing on a printed photo of their area of excavation”, also made searchable by unit of feature number. Preliminary research by Allison Mickel shows significant overlap between the information content of unit and feature recording sheets on the one hand, and personal diaries on the other. She concludes that “it would be ideal to connect the diaries, the daily sketches, the excavation data, and even the photos and videos collected at Çatalhöyük—to make it possible for researchers and the public to navigate between these media in intuitive ways”, especially in light of the fact that excavation data “must be published and archived in full” as the multiyear excavation project comes to an end [104].

According to the Çatalhöyük team, the key factor that established excavator diaries as an effective instrument for “information at the trowel’s edge” was the distribution of digital tablets to members of the excavation team,

[...] a suitable replacement for the traditionally hand-drawn graphic archive [...] an indispensable repository of all past and present information relevant to the excavation, channelling a variety of data types. Archive reports, containing relevant information about previous excavation seasons, became available at the touch of a finger. [...] The team members very quickly begin to develop a much deeper understanding for the digital data structure of the project and, by implication, what happens to the data once it leaves the site and how it fits into the process of interpretation. The tablets bring many aspects of data manipulation, validation, and interpretations, which are ordinarily reserved for certain ‘privileged’ individuals during the post-excavation process, into the field at the trowel’s edge. [98]

Personal and reflexive video recording has also been practised in Çatalhöyük for many years [114], but it is only in 2013 that a portable digital recording device was provided as a tool of personal recording to excavation team members, supplemented by video annotation and bookmarking software. Participants in this pilot project were encouraged to record video segments to capture interesting scenes and activities during the excavation, and, after the end of the day, to “re-visit” the captured scenes, bookmark, annotate particular points of interest, and respond to a semi-open video interview on the day’s proceedings. Some chose to record *in situ* conversations capturing different conjectures, questions and interpretations as the excavation unfolded. Others captured recordings of a particular location, while excavating, moving, pointing, and, in some cases, commenting verbally as an *aide memoire* for later review. Thus, “video stands as a bridge connecting the current state with the previous state and the respective processes involved”, allowing later scrutiny of particular actions and interpretations, for the benefit of not only the individual researcher concerned but, with her consent, of other members of the research team including lab specialists who may not even be present at the excavation. Gestures captured by such videos, as well as specific performative activities such as trowelling, add “another layer of documentation [...] to do with the elusive processes and modes of interacting with the archaeological material” [102]. This layer of documentation may capture the “rich physical variety – material traces of plows, burrowing rodents, etc. – in the actual dirt that it is [the archaeologist’s] job to excavate”, as well as “environmentally coupled” actions such as demarcating a feature in the dirt with the trowel [52]. The moment the pragmatic, embodied interactions of an archaeologist get captured by way of reflexive video recording, bookmarked and annotated, they become curated information objects enriching the record of the excavation for current and future use.

In fact, both personal diary entries and reflexive videos in Çatalhöyük are effective, if currently limited, forms of curation of particular archaeological entities (units, features, and buildings) found in the site database, or of other, mostly intangible, contextual aspects of the archaeological record such as those related with substantive and methodological questions relevant to the excavation *and* the site. The prospect of allowing a community of researchers to annotate, challenge, and qualify the “institutional facts” [42] stored in the database, and to refute or lend support to earlier identifications and interpretations through personal diaries and reflexive video recording, points to an intriguing practice of adding value to the archaeological record by means of “exercising the archive” [33] of the excavation which addresses all four methodological tenets of *reflexivity*, *contextuality*, *interactivity* and *multivocality* advocated by the Çatalhöyük team.

The deployment of a full array of curation strategies leveraging the affordances of rich, interactive technological infrastructures and methods in Çatalhöyük is exemplified in the work of Maurizio Forte and his team, aiming “to reproduce, virtually, the whole archaeological excavation process using laser scanners and 3D photogrammetry on site, and 3D Virtual Reality collaborative systems during the post-excavation interpretation and analysis in the lab” [115]. This materializes Paul Reilly’s pioneering vision of “virtual archaeology” as a radical digital approach to archaeological preservation [116]. Forte’s team use SLR cameras and the internal camera of a digital tablet to capture digital photos of the excavation, and process them, after digital photo rectification, vector extraction, and geo-referencing, into an accurate 3D model, allowing “the drawer and the excavation team to check the digital map during the excavation” [103]. All digital drawings and models produced in situ are then integrated with other data into a complete record of the excavation in a Geographic Information System. The process aims at accuracy of recording (to “always under 1 cm”) and minimization of mistakes. Their primary objective is to integrate assessment of archaeological *evidence* with interpretation in real time, by integrating real time 3D capture and georeferencing with the ability to simulate the excavation within an immersive, interactive 3D simulation using head and hand tracking equipment and real time computer graphics:

[...] each stage of the excavation process is documented as the work progresses, and can be reviewed immediately using 3D models. At the end of each day, therefore, everyone from all disciplines involved in the excavation can visit the virtual dig, as if standing on site as the work took place (see image on p.38). This allows the archaeologists to re-examine the evidence as it appeared, pooling their expertise. [115]

While emphasis is given here to the *synchronous* use of the rich and contextually linked information and visualization of the archaeological process in real time, curation in Çatalhöyük also affords an important diachronic function. The speed of capturing digital photos in Forte’s excavation sector helps minimize the time of exposure of fragile burial remains, by allowing plans to be drawn later from the photographic evidence, thus pre-figuring a continuous process of curation bridging excavation with post-excavation. And the geo-referenced 3D models of the excavation, together with the diverse annotations, interpretations and the related contextual information, are explicitly produced in order to remain available, and useful, for subsequent research, publication, and public interpretation.

Furthermore, differences in the production of the archaeological record by virtue of diverse digging, identification, recording and curation methodologies, and priorities have considerable impact for the comparability of the archaeological record as evidence for subsequent, post-excavation research. Indeed, archaeologists working on the all-important Çatalhöyük corpus of clay figurines cannot fail to observe that “Mellaart in the 1960s, the current core excavation team, and the recent semi-autonomous Turkish, Polish, Greek and North American teams, digging different areas [...] with different methods, have produced sometimes different archaeological ‘records’” [117]. Tringham and Stevanovic, comparing the excavation approach of their own Berkeley team with that adopted by their Cambridge colleagues in other sectors of the site, conclude that “different excavation styles create different windows into Çatalhöyük”, stressing the implication of differences in research questions, intellectual histories and field experience of researchers on the definition of recording units, work organization roles, digging styles, and, even, the articulation between recording and interpretation. As they note, the “almost neatly defined areas of the Cambridge team in the North area” are in sharp contrast to “the mass of complicated fill and history of collapse and

destruction” in their own sector. Whereas the Cambridge team views “buildings as self-contained units, the [Berkeley] team studies the Neolithic buildings at Çatalhöyük as part of a network (or “anthill”) of rooms in which it is hard to say where one “building” begins and where it ends [118]. The curation practices of the two teams, and the database structures representing these two different ontological stances vis-à-vis the units of analysis and the cultural interpretation of their interrelationships, are understandably and notably different.

Excavation-based research is typically published, besides journal papers and monographs, in the relatively standardized genre of an archaeological report, providing a synthetic summary followed by “a description of investigation process, a survey of related literature and an interpretation of the results of the investigation. The description is followed by a catalogue of finds unearthed during the project, a list of photographs, plans, drawings and samples” [119]. The work of the Çatalhöyük excavators is notable in its purposeful, and consummately theorized effort to go beyond the printed report, and even the online publication of digital data and documentation resources on the Çatalhöyük website, by way of authoring of a whole spectrum of experimental digital publication formats. These use an almost baffling array of multiple strategies: constructing multiple narratives in *ChimeraWeb/Dead Women Tell No Tales* [99], “wayfaring” by way of video walks in *Remediating Places*, virtual world simulation in *Okapi Island in Second Life* [100, 120], “remixing” in *Remixing Çatalhöyük*, and “remediating” in *Senses of Place* [121]. As I have argued, they may also be seen as instantiation of diverse genres of “virtualization” [122]: virtualization of artefacts, integrating digital surrogates and extensive documentation connecting finds with contexts; spatial visualization, adopting the metaphor of virtual travel to creat[e] a sense of place for virtual visitors, an important concern for phenomenological and reflexive approaches such as the one explicitly adopted by the site’s excavators; virtualization of experience, e.g., in the case of the *CatVidPlace* digital project, expanding the “sensorium” of researchers and visitors through video/sound walks, memory and performance [123]; and, virtualization of the archaeological process, through the integration of personal digital diaries, video recordings of dig meetings, local community knowledge of the site, interpretive annotations in the context sheets and other structured documentation of the dig, and multiple 3D simulations of the site as it is being excavated [101, 124].

As Morgan reports, the Open Knowledge and the Public Interest research group digitally recreated Çatalhöyük in the virtual environment of Second Life as a tool for exploring alternative interpretations and supporting educational activities. Her experiment with modelling, rendering, and lighting a room interior raises interesting questions on how the walls were plastered, how smoke from the oven would be evacuated, on field photography requirements for building reconstruction, and more generally on the goals and methods of virtual archaeology [100]. Another team, from the University of Karlsruhe, notes the concern of archaeologists that – far from Hodder’s call for “less sacred, less sterile, more animated” representations – the complete, exact and realistic-looking nature of 3D reconstruction of the site obscured the ambiguity and nuance of what they actually saw in the site [125]. The application of 3D reconstruction and site visualization technologies in Çatalhöyük highlights thus salient epistemological questions on the value of sensuous properties of digital reconstructions for archaeological knowledge given the partiality and theory-ladenness of the archaeological record, and relevant to recent theoretical contributions towards an archaeology of the senses [126, 127].

Two recent publications by Çatalhöyük investigators provide illuminating insights not only on the achievements but also on the problems revealed by the project, as it now approaches its final few seasons. A study of the integration of digital and 3D technologies in the project, co-authored by a team of Çatalhöyük investigators led by Åsa Berggren, acknowledges that Hodder’s twelve-point plan towards reflexive practice was achieved only partially, suggesting that the reason for these “inconsistent results may be that reflexivity at the beginning of the project was regarded as a methodological matter, with reflexive methods added as an envelope surrounding excavation and recording” [98]. Authors note, in particular, that different perspectives introduced by teams of different nationalities and approaches “also resulted in a fragmentation of the project”, while the on-site interactions during the so-called priority tours of laboratory staff in the excavation illuminated a “structural imbalance” between “excavators coming mainly from the developer-funded world and academic researchers based in the laboratories” [98]. On the other

hand, Shahina Farid's insider review of the Çatalhöyük experience from 1993 to 2011 [128] reiterates even more candidly the inconsistencies in the application of plans towards reflexive practice and the mounting tensions between different teams, which in 2011 led to the introduction of major changes to the project including a "wholesale change of its longstanding personnel [and] mixing excavation teams" [128]. Both studies confirm that the adoption of digitally-enabled methods such as digital tablet-based diaries, on-site virtual reality reconstruction, and just-in-time database access of lab-based interpretation to the excavation process does introduce new opportunities but also sociotechnical and epistemological challenges. As Berggren and co-authors admit, "[t]he 'reflexive loop' might be seen as an ideal, although historically it has been difficult to implement fully" [98].

Yet the "structural imbalance" between excavators whose main role was to produce, record and preserve the archaeological record, and laboratory researchers deemed to be responsible for synthesis and interpretation, became manifest in Çatalhöyük exactly because of the purposeful, if not fully realized, attempt to bring together the two processes of recording and interpretation "at the trowel's edge".

The phenomenon finds parallels in other archaeological fieldwork projects, which point at the interdependence between data construction and interpretation across the research life-cycle. In his important ethnographic study of an archaeological excavation in Britain in 1989-90, Matt Edgeworth reports that

[...] the emergence of surprising, unexpected, contradictory, or difficult evidence [...] rarely appeared in fully fledged form all at once but rather unfolded over time as it was being worked. Existing archaeological knowledge was being applied to shape and make sense of the material evidence at the same time as the material evidence was reshaping the knowledge that was being applied. [129]

The recording of documentary evidence from the excavation process appears thus to co-evolve with the production of archaeological knowledge. In fact, while fieldwork sometimes works through "vertical tacking" – documenting the observable record of the excavation process, and then seeking regularities and explanation through analogy with known facts – the identification, description and curation of the archaeological record "is increasingly conducted as a testing procedure; evidence is sought (following something akin to Collingwood's logic of 'question and answer', 1978) that is specifically relevant to the question whether it is likely that a particular past context instantiated the reconstructive models archaeologists bring to it" [130]. While the availability of multimodal, interactive, real time recording, and documentation technologies in the field moves interpretation *upstream* to the very moment of digging and *in situ* recording, conversely, the availability of the excavation archive through the active research process (which, in archaeology, can be prolonged for many years of continuous effort) in a hyperlinked database, and multiple digital publication genres, combining also interpretive narratives, 3D models, mapping, and video documentation, extends the process of recording and documentation *downstream*. Since archaeological interpretation using the single-context recording system depends on the identification of the associations of individual contexts within the stratigraphic matrix, it is common for irregularities to appear to archaeologists as they make sense of the spatiotemporal relations between contexts in the light of already established facts and archaeological theories, and the record produced at excavation time remains open to systematic doubt, re-evaluation and continuous enrichment and change. Indeed, Reuben Thorpe notes, the "process of generating both data and what Binford (1972:159) called 'running analysis' involves the dynamic interplay of participatory observation and association within a framework of *stratigraphic possibility*" (added emphasis) [108].

This account sheds light on archaeological knowledge production work in Çatalhöyük as curation. Archaeologists routinely engage in the full life-cycle of planning, appraisal, capture, description, annotation, categorization, modification, knowledge enrichment through interpretation, and dissemination of a diverse range of overlapping, and recursively interrelated, records. This includes computerized single-context sheet documentation, digital diaries and audio memos, digital photography, reflexive video recording, sketching and drawing, stratigraphic sequence matrices, 3D models, GIS representations, hypertextual and narrative interpretations of particular archaeological entities, and their relationships, leading to multiple genres of

publication from archaeological reports to corpora, online databases, monographs, and research journal articles. Digital mediation, in particular the combination of relational database recording with hypertext linking of diverse documents and media, moves the interpretation process, to some extent, from the intrinsic rhetorical form of a single text to the connections made between diverse morselized information objects. A process of pluralizing [131] is exemplified both in the production and juxtaposition of multiple (textual, diagrammatic, simulated 3D, mapping), overlapping, and cross-referenced representations of what was found, and in the multiple voices of members of the excavation team as they engage *on record* in conjecture, critique, dialogue, reflexive introspection, and interpretation.

The archaeological record is thus created gradually, in a process of active curation, involving not just mere transfer of what exists in the archaeological site as it is excavated, but also a knowledge-saturated process of cognition and action that has an impact on the entire lifecycle of the excavation process, from the identification and selection of archaeological “institutional facts” as decisions are made on what to excavate and how, to their description, interpretation, ordering, analysis, and presentation. The construction of the archaeological record is not only inextricably linked with theory, but involves also constant contestation and negotiation between excavators and laboratory researchers, amateurs and professionals, and the complementary functions of preservation and interpretation. Methods such as the single context sheet and digital tablet recording, and practices such as *in situ* 3D visualization and access to an integrated finds database, become the new “contact zones” [cf. 132, 133] for such contestation and negotiation.

While it may have been argued that “excavation and curation are qualitatively different encounters between researchers and the material remains of the past” [44], *upstreaming* the act of interpretation “at the trowel’s edge” – as was very much the case with traditional field archaeology using the feature-group recording system – suggests that the initial construction of the archaeological record during excavation is actually inseparable from curation. And, *downstreaming* the process of description and representation beyond the initial construction of the excavation database, up to the point of the digital publication of the excavation, means that the entire practice of creating, managing and using the archaeological record is permeated, again, by a kind of curation that spans the continuum of the archaeological research process, transcends the boundaries separating the field from the screen, and re-inserts essential questions of data constitution and representation to the realm of interpretation.

## 4 Towards intelligent, pervasive digital curation

Digital curation emerged in the beginning of the 21<sup>st</sup> century as a burgeoning research community, field of practice, and constellation of professional norms, methods and tools aimed at “maintaining, preserving and adding value to digital research data throughout its lifecycle” [134]. It stemmed from the confluence between the research and institutional agendas related to digital preservation and e-science data management. In line with earlier work on digital preservation, digital curation research agendas, processes and systems have mostly focused on the development of appropriate solutions, procedures and institutional arrangements that would facilitate the accession and long-term preservation and access of primary research materials in “trusted” repositories [135]. In this context, digital curation is considered as the purview of information professionals [136], involving, notably, the “selection and appraisal by creators and archivists; evolving provision of intellectual access; redundant storage; data transformations; and, for some materials, a commitment to long-term preservation” [135]. Indeed, it is academic researchers in computer science and information science, and professionals in libraries, digital archives and databases, that reign supreme over digital curation, and elements such as preservation metadata and interoperability standards, trusted repository certification, cost models, and risk management that dominate its research agenda and repertoire of digital tools and services [33].

While this dominant conceptualization of digital curation can be valuable to the strategy of depositing archaeological data and resources into secondary archaeological research archives and repositories such as ADS and tDAR, it is uncertain how it could possibly address the pervasive curation challenges of the emerging landscape of archaeological research, as illustrated in the examples, issues, and extended case

study presented so far in this paper. This dominant approach is characterized by an adherence to a notion of fixity, whereby data objects are considered to be invariant and the preservation of their integrity and authenticity is the predominant consideration, a focus on developing norms, procedures and standards not normally applicable outside the custodial world of trusted repositories and information professionals, and a presumption of normativity and universality of actual practice. These tenets are in sharp dissonance with the messy and complex domain of *in situ* and *in vivo* archaeological research, the hybrid and epistemic nature of archaeological data, the biographical, distributed and dynamic character of archaeological entities, and the multiple contexts, multiple intentionalities, and media affordances shaping their meaning. This mismatch is not restricted to archaeology, but is also apparent in the practices of biocurators [32], museum curators and visitors [33].

Partially in response to these challenges, the last few years saw a *practice turn* in the field of digital curation. Archival science scholar Elisabeth Yakel argued that digital curation is intended to be “an active and potentially interactive process with records creators” [136], workers in the DigCurV project called for extending digital curation education to research practitioners, managers, executives [137], data creators [138] and individual users [139], Liz Lyon of the UK’s Digital Curation Centre led a study of context-specific disciplinary practices of digital curation [140], while, more recently, Cal Lee of the University of North Carolina’s Digital Curation Curriculum initiative, produced an edited volume of studies among which several touch on the digital curation of personal collections [141]. In our work on the digital curation life-cycle at the Athens-based Digital Curation Unit (DCU), Panos Constantopoulos and I called for the explicit inclusion of processes related to the production of knowledge, its public communication and user experience in digital curation, spanning across the records continuum to encompass digital objects before they enter a custodial environment [142]. Drawing from an approach that views digital curation as a “purposeful interaction of a subject with the world”, in other words as a composite cultural-historical activity fulfilling specific motives and goals, and enacted through the mediation of “tools” such as frameworks of domain knowledge, norms and standards, methods and procedures, and digital infrastructures [33], we also developed an ontological Scholarly Research Activity Model [143] compatible with the familiar CIDOC Conceptual Reference Model [144], which could be applicable to the formal representation of digital curation activity across the continuum of archaeological research practice.

## 5 A grand challenge: archaeological digital curation in the continuum

While practice-centred moves such as those introduced in the last section pave the way for a more inclusive approach to addressing aspects of archaeological digital curation based on Web 2.0, social media and open archaeology, as well as those witnessed in the Çatalhöyük excavation, the research questions which practices “in the wild” introduce are formidable. Addressing them calls for a programmatic initiative that involves multiple teams of experts, spans across disciplinary boundaries, encompasses ontological and epistemological considerations, and necessitates a collaborative, multiyear inquiry, bridging the functions of discovery, integration and application introduced by Ernest Boyer’s familiar conceptualization of scholarship [145].

The initiative I advocate draws from epistemological traditions of pragmatism [146, 147] and critical realism [148, 149] and is two-pronged: it aims at the same time at *representing* archaeological digital curation in a way that can account for emerging practices of archaeological curation “from the field to the screen”, and at *intervening* on future digital curation praxis, research agendas, and sociotechnical arrangements (i.e. on the ways of “doing archaeological curation digitally”). It is based on a conceptualization of archaeological curation as an epistemic and pragmatic *activity*, which encompasses information processes related to the making of knowledge in the “thick and thin” of archaeological research, and to its relevance for heritage management, sociocultural contestation and appropriation. In turn, this conceptualization provides a framework for focused inquiry on archaeological *objects*, *practices*, and digital *infrastructures*,

for archaeological research (fig. 1). Objects encompass, in this conceptualization, not just the “primary” material vestiges of humanity but also those epistemic, social objects – reproductions, models, and also different genres of documents – that act as mediators for the construction and interpretation of the archaeological record. Practices range from the selective capture and description of archaeological field realities to classification, interpretation, preservation and use by diverse actors, for different purposes and in particular contexts. Finally, digital infrastructures include a wide range of hardware and software systems, services and tools, devices and interfaces – some of them global, networked and ubiquitous - involved in the production, interpretation, preservation and use of the archaeological record. These four areas hinge on latent ontological dimensions of *agency*, *process* and *object*, salient for considerations of archaeological and material culture theory on the one hand, and for digital curation and information theory on the other. I have already been engaging with the theoretical implications of one aspect of this research programme in the context of a broader investigation of the digital curation of “thing cultures”, focusing on objectual practices involving historical (cultural) things in scholarly and other contexts [150].

In the last section of this paper, I outline the objectives, background, and main prospective elements of each of the four areas of the proposed research programme. I argue that digital curation in the continuum of the pervasive, distributed, and ubiquitous digital infrastructures that increasingly colonize archaeological practice, as well as in the continuum of multiple stakeholders, contestations and negotiations spanning from commercial archaeology to community engagement, is a grand challenge that requires the mobilization of multiple interdisciplinary teams of researchers. However, while I advocate that the problems it entails apply to all of us, it is reasonable to assume that different research teams may develop complementary, alternative, and even opposed solutions and approaches to address them. The aspects of the research agenda outlined below represent mostly the research initiated and planned by my colleagues in the Athens-based Digital Curation Unit and myself. They are presented here in order to initiate constructive dialogue on the grand challenge of archaeological digital curation in the continuum with a broader community of researchers concerned with the constitution and management of the archaeological record in the digital domain.

## 5.1 Developing an operational theory of archaeological digital curation as an epistemic and pragmatic activity in the continuum

Drawing from cultural-historical activity theory and practice studies, I advocate the need to develop a formal conceptualization of archaeological digital curation in the form of an ontology, amenable to operationalization for the analysis of archaeological entities and practice, and open to the multiple and evolving aspects and stakeholders of archaeological work in the continuum. Such an ontology should allow the elicitation of inferences on salient aspects of archaeological work, such as the articulation of middle range theories with data, the analysis of archaeological discourse, the elucidation of the notion of archaeological method, and the applicability of particular criteria, methods, procedures, and tools in real-world archaeological problems, involving multiple stakeholders beyond professional and academic archaeologists. It will also be useful for the development of knowledge bases, decision support systems, semi-automated and assisted services to facilitate archaeologists in digitally-enabled research, as well as for encouraging reflexivity with regard to the methods of archaeological work and their theoretical and pragmatic entailments.

I have proposed that archaeological digital curation, as witnessed in Çatalhöyük and other examples, concerns not only the epistemic context [151] of the archaeological record but also its epistemic *content*. Archaeologists do not merely appraise, arrange, and describe archaeological data *qua* records; rather they actively construct and manipulate event-centric representations [144] not only of information objects representing archaeological entities, but also of the people, places, events, social practices, norms, and cultural forms which these entities represent. Curation manifests itself as representations becoming semantically enriched, as multiple interpretive communities “exercise the archive” of the archaeological record, and as archaeological knowledge evolves. This is the reason why I had argued that digital curation, here as an aspect of archaeological professional practice, should be supported by methods, procedures and tools capable of allowing “the active ‘questioning’, dynamic co-evolution and adequate representation

of [the] epistemic/pragmatic content and context” [33]. This extension to a widely accepted definition of digital curation [134] links archaeological digital curation research more explicitly to questions of knowledge representation, data constitution, and scholarly argumentation.

The DCU model of digital curation processes [142] may be seen as a significant extension of the widely known curation life-cycle model of the UK’s Digital Curation Centre [152], based on such a broader conceptualization of digital curation. By virtue of this, it may be used as a suitable conceptual structure for a research agenda which includes the *appraisal* and *experience* of archaeological entities “in the wild”, archaeological *knowledge enhancement* and *presentation*, *goal* and *usage modelling* to account for archaeological agency, and *domain modelling* and *authority management* [142], to capture and categorize evolving aspects of the archaeological record. This model can reach beyond the custodial fold of secondary archaeological archives and repositories to encompass digital curation from “the trowel’s edge” to dynamic online publication, review, and annotation. On the other hand, the complementary in scope Scholarly Research Activity Model [143], developed by the DCU on the basis of an evidence-based study of scholarly research processes in archaeology, history and other humanistic disciplines [153, 154], may serve as a useful foundation for capturing salient dimensions of archaeological curation in practice. These include the differentiation between normative and actualistic aspects of archaeological research practice (i.e., between a method or established procedure and its application), the interaction of multiple actors (including archaeologists, local and source communities, and audiences) and their motives and goals, the sociotechnical adoption of methods, procedures, tools and services by archaeological communities of practice, the primacy of indexed “things in the world” for archaeological interpretation, and the multiple actions of curating archaeological information entities (e.g., refers to, creates, updates, annotates, classifies, aggregates, samples, modifies, etc.) and syllogisms (e.g., refers to, represents, posits, supports, rebuts, undermines, expands, specializes, etc.) (fig. 1).

The rationale for ontological work on archaeological digital curation, its multiple actors and its “deep structure” stems from the crucial ethical, political and epistemological impact of the operation of multiple fields (including that of cultural resource management, and cultural contestation and appropriation) on how we perceive the formation, curation and use of the archaeological record and archaeology as a discipline and field of practice. As noted by Ferris, archaeologist and community-based viewpoints may produce entirely different ontologies: “Native histories differ markedly from archaeological histories in terms of their emphasis on human behaviour, documentary and oral information, and distinctive conceptions of time, self, and narration” [72]. When approached from the viewpoint of information systems, tools and services, archaeological processes are all too often shoe-horned into linear “waterfall” workflows, ignoring the recursive and non-procedural aspects of much archaeological work, and the discursive nature of archaeological interpretation, which goes beyond argumentation structure to encompass power-laden situations, positional relations of actors, and intentionalities.

On the other hand, current ontological approaches often present a normative view of processes of curation, which accounts poorly for the duality of practice, and makes it difficult, if at all possible, to accommodate change and fluidity occurring as actual archaeologists “exercise the archive”. For example, given current approaches it is not possible to account formally for the fact, noted by Eric Kansa et al., that in the context of institutional repositories an archaeological “researcher’s primary responsibility toward data currently centers on preservation [...] a new normative best practice [which we question if it is] sufficient to deal with the realities and complexities of data reuse” [88]. In the light, in particular, of developments in open and participatory archaeology, Limp is justified in expressing the belief “that the initial hard ontological/semantic work has not yet been done for archaeology” [91]. Significant further development of an ontological model for archaeological digital curation is necessary in order to make it pragmatically useful to capture the structure of digital archaeological work, as it relates to the continuous curation of the archaeological record. Current collaborative work towards the conceptualization, design and deployment of the NeDiMAH Methods Ontology (NeMO) for digital

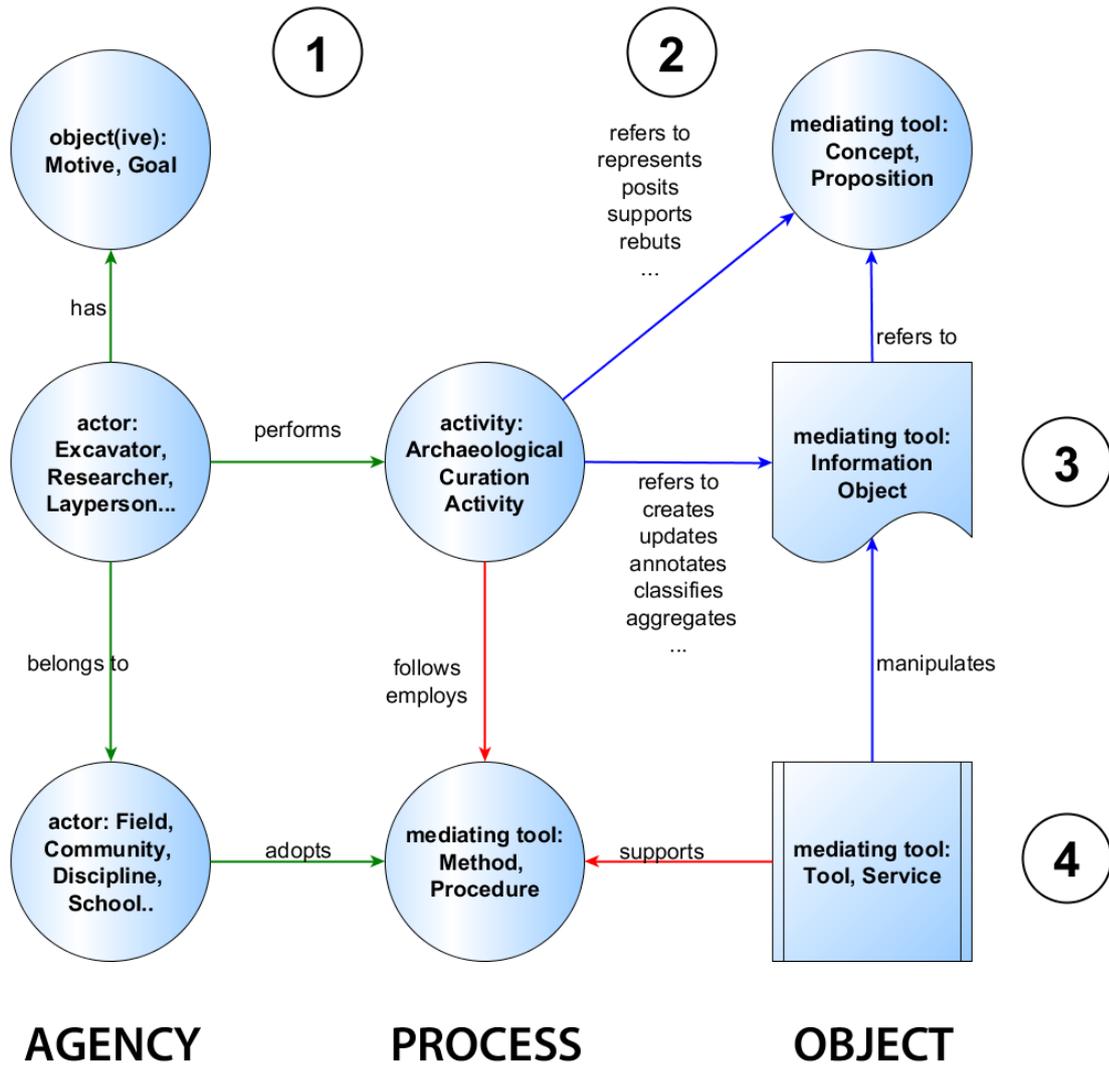


Figure 1 Archaeological curation core activity model

humanities research, supported by a combination of expert knowledge elicitation and representative case studies from actual research practice [155], may allow us to ask questions such as the following:

- To what extent can we confirm, or refute, the structure of digital curation activity in the light of eliciting experiences of practice in archaeological work?
- To what extent can (or, should) we express digital archaeological methods as sequences of steps, or “recipes”?
- Which form do archaeological traditions, or cultures, take in shaping actual research activity?
- How can we account adequately for the emergence of new norms, methods and established procedures from changing archaeological curation practice?
- How can we account for local knowledge as manifested in contemporary ethnoarchaeological interactions, and in the practices of public and indigenous archaeology?

Such questions, as well as the overarching agential structure of digital curation, cannot be elucidated without *integrative* medium term theoretical inquiry. This draws on *discovery*-oriented research on two complementary dimensions – the representation of the archaeological entities on one hand, and of practices on the other – and from related *application*-oriented experimentation with operational models of

digital curation in an archaeological context employing digital infrastructures, tools and services [cf. 145]. These further areas of the proposed research agenda are summarized below.

## 5.2 Representing archaeological entities as objects of curation

Digital curation of archaeological entities (as they emerge through fieldwork and collections-based research) requires adequate representation of their provenance, function and significance in the past, as well as their diachronic cultural biography and their pragmatic efficacy in the present – for example, when they are placed in encounters with local knowledge and cultural contestation [4, 156]. It also involves representation of constructed epistemic objects – archaeological reports, through which archaeological entities become objects of knowledge [122]. What makes a good formal representation of archaeological entities becomes, thus, a crucial question.

Accounting for object complexity, the usefulness of ontological approaches to capture biographical dimensions, and the pragmatic nature of data constitution in the context of a process of interpretation, curation and use of archaeological entities constitute salient aspects of this research objective. An earlier inquiry on the applicability of alternative syntactic formalisms - trees, geometric transformations, semantic paths, rewrite-rule grammars – to represent scenes on Classical Attic grave reliefs [157] revealed different affordances for archaeological objects which, way beyond what can be expressed by the assemblage-artefact-type model [12], may belong to multiple categories arranged in often multiple and tangled specialization hierarchies, exhibiting a compositional structure, changing dynamically through time, situated in historical space, known partially and subjectively, and dependent on multiple contexts [158]. Being “heterogeneous and diverse, complex in terms of part composition and meaning layering, and densely connected with other important information objects, such as periods and events, places, time intervals and relationships, people and [their] possible associations”, archaeological objects call for an ontological approach to the representation of the archaeological domain, such as presented by the CIDOC Conceptual Reference Model (CIDOC CRM) [159], the widely accepted standard ontology (ISO 21127) for cultural information.

Current work in the Advanced Research Infrastructure for Archaeological Dataset Networking in Europe (ARIADNE) aims to develop an event-centric ontological representation of archaeological excavation by means of CRM<sub>archaeo</sub> [160], a lower ontology extension of CIDOC CRM and the CIDOCsig digital provenance model [161]. Another, potentially fruitful strand of work within ARIADNE builds on an alternative, “wide and shallow” Cultural Heritage Abstract Reference Model (CHARM) [162] aiming to account explicitly for subjectivity and discursiveness in archaeological entity representation.

Yet, the multiple ontologies emerging from ethnoarchaeological and indigenous material culture contexts [133, 163, 164] make the case for a fundamental re-examination of the formal representation of archaeological entities, calling attention to the emergent character of object categorization, the virtues of free structure representation languages for description and classification, and the discursive and pragmatic dimension of archaeological argumentation [165, 166]. In my ongoing theoretical inquiry on the “digital curation of thing cultures” I draw from postmodernist archival notions of context [167], indigenous curation and local knowledge ontologies [168, 163, 164], and four-dimensionality [169] to question the ontological distinction between objects and events, particulars, and categories, and conceptual and physical aspects of existence accepted by standard archaeological documentation practice and its formal conceptualization in *CIDOC CRM* and related models. One radical alternative I have been exploring is to conceptualize archaeological *things* as *eventful and kindful conceptual-physical objects*, accounting for the challenges to Eurocentric models of categorization by indigenous and vernacular ontologies, and the diachronic dimension of archaeological and cultural heritage (e.g., by reflecting on the regularly reconstructed Shinto Shrines of Japan as a “ship of Theseus” [169, 170]).

While these are initial points of departure, significant further research, engaging multiple investigators and viewpoints, is needed to account for the multiple and fluid ontologies governing artefact-based negotiations of meaning and identity in contemporary, post-colonial and multicultural societies, the biographical and diachronic nature of material things, and the increasing import of knowledge organization and representation in contemporary digital infrastructures.

### 5.3 Accounting for archaeological curation practice and methods

In the light of approaches that prioritize the properties and relationships of data and the affordances of digital systems as the main focus of archaeological curation, I argue that it is necessary to engage in extensive multi-methodological research focusing not on data or systems, but on the practices related to the construction and curation of the archaeological record, including nomothetic and idiographic, quantitative and qualitative, positivist and interpretive approaches, and covering not just archaeological data management, fieldwork, laboratory and artefact-based analysis, but also cultural resource management and archaeological interpretation. This is even more so given the significant changes introduced due to the increased import of pervasive digital infrastructures and the involvement of multiple stakeholders in archaeological work. A formal understanding of digital archaeological methods, tools, actors and resources, and the relationships binding them, may find a reliable foundation in an evidence-based inquiry on actual archaeological practice.

Earlier qualitative and mixed methods research by my DCU colleagues and myself on scholarly practices and digital needs of humanities researchers, including archaeologists, confirmed the validity of a categorization of research processes such as digital and non-digital information seeking, resource organization, processing, collaboration, and dissemination [154]. In tandem with information seeking, we found that archaeologists also engage in the active curation of a continuous range between data and scholarly objects, transforming “raw” into “institutional” facts [42] through description, classification, interpretation and publication. Through annotating, organising, and versioning activities, they curate the conceptual representations not just of archaeological artefacts and features encountered, but also of activities, cultures, people, concepts, places, and other related entities.

As Lake argues, the networked environments in which open archaeology and open data operate not only produce greater opportunities for community engagement but also “bring into sharper focus the question of what communities actually want” [85]. Yet extensive research on the whole range of archaeological practices by archaeologists and non-archaeologists in the continuum is still rare [40, 119, 129, 171] and sorely needed, as argued also by Kansa et al. with regard to data reuse [88]. In a related yet significant field of archaeological activity, Huggett concurs that “relatively little attention has been paid to the detailed consideration of process in the creation of archaeological standards, and, where detailed discussions with user-groups, communities and others have taken place, this is poorly reflected within the literature”, and calls for “an ethnographic study of archaeologists undertaking the construction of ontologies, given the present emphasis on these for the next generation of web tools” [172]. While nominally an inquiry into the “the structures which are being created for representing, locating and retrieving archaeological data” [172], Huggett’s call can be understood, in my view, as a rationale for studying more broadly, through ethnographic research, all aspects of archaeological categorization and meaning-making practice, encompassing objects (data, resources), process (activity) and agency (intentionality).

In my present examination of contemporary archaeological curation “in the wild”, I also note how the archaeological record is constructed dynamically *in situ* as the excavation progresses through a combination of diverse “mediational artefacts”, and how curation is based greatly on the incorporation of conjectures and questions to serve later use. The situation is not dissimilar to what ethnomethodologist Harold Garfinkel pointed at in the medical consultation context, whereby outpatient ward dossiers are better understood as “therapeutical contracts” than as “actuarial records” [173]. In juxtaposition with positivist accounts of “scientific process” which views archaeology as one of the natural sciences [174], the account of archaeological fieldwork in Çatalhöyük and other examples of contemporary practice which I presented in this paper highlights the need to refine our conceptualizations of archaeological practice so that they account for its purposeful, discursive nature, in line with earlier work on scholarly activity conceptual modeling inspired by cultural-historical activity theory. This view resonates with Margaret Conkey and Joan Gero’s call “to increase the visibility of human agency in knowledge production, becoming more conscious of, and making more public the choices that accumulate into what is known about the past” and “to organize archaeological field projects in less hierarchical fashions, avoiding the situation of a single unchallengeable authority who pronounces judgments from the top” [175], adopted by Morgan

and Eve in their “radically transparent” practice of sharing current interpretations and interim excavation reports as a vindication of a politically and theoretically informed interpretive digital archaeology [86].

Work under the newly-founded Digital Methods and Practices Observatory (DiMPO) Working Group of the Digital Research Infrastructure for the Arts and Humanities (DARIAH-EU, <http://www.dariah.eu>) includes a project to build a formal account of digital methods in the arts and humanities through the development and curation of the lower layer of the NeMO ontology [155], based on the formal description and contextual documentation of particular digital research methods, historical accounts of how researchers have used them, and futures research. In parallel, members of the ARIADNE Special Interest Group on Archaeological Research Practices and Methods are engaged in futures research [176–178] based on expert knowledge elicitation to envision scenarios of digital archaeology research practices in 2020–25. This work is hoped to further elaborate the task of re-examining the scope, purpose and methods of archaeological digital curation in the light of the properties of pervasive practices of curation “in the wild”. Yet significantly larger research effort, involving multiple teams of researchers, is needed in order to develop concrete and fully formalized accounts of research practices and methods for particular aspects of fieldwork, and substantiate a definition of archaeological digital curation (and its concepts, methods and tools) as an end-to-end, pervasive activity in the emerging continuum of digital information, connected with the growing importance of ubiquitous and networked digital infrastructures for archaeology.

#### **5.4 Building archaeological curation functionalities for pervasive digital infrastructures**

While there has been considerable effort to develop protocols, standards and systems for the deposition of archaeological records to secondary digital archaeological archives and repositories, for archaeological metadata aggregation and for the design and development of curation-enabled repositories, there has so far been little forethought or planning in developing curation functionalities that can work in synergy with the pervasive, commercially driven, and increasingly closed global digital infrastructures on which archaeological curation “in the wild” depends.

The affordances of digital tools and services used for archaeological research – databases, digital repositories, digital libraries, multimedia platforms, mobile devices, digital capture equipment, etc. – have a significant effect on the nature of curation activity they enable and constrain. The semantics of these digital infrastructures cannot be subsumed in their formal description, since it also entails sociotechnical arrangements and tacit knowledge. The only way to ensure that specifications match requirements is to take stock of actual practices and user needs, and to be involved pragmatically in the specification, design and deployment of actual digital infrastructures. Further to that, the complexity and theory-ladenness of archaeological data, the interdependence between processes of description and interpretation, and the pervasiveness and distributed nature of digital tools and services used by archaeologists as they curate archaeological information, argue for a rethinking of the digital infrastructure from a centralized and custodial to a distributed sociotechnical architecture, able to support archaeological knowledge work.

As early as the 1990s, the functional specification of the MITOS/CLIO semantic information system aimed to capture and support the generation of objects and collections related knowledge in the Benaki Museum in Athens “across [the museum’s] heterogeneous collections for research-related activities, such as the preparation of exhibitions and the production of catalogues” [179]. A precursor to the work that led to the development of the influential CIDOC Conceptual Reference Model (CIDOC CRM) [144, 180], CLIO was based on a knowledge representation language which offered powerful mechanisms of classification and specialization typical of material culture, could express uncertainty and complexity in temporal relations [181–183], represent cultural biographies of objects, support multiple vocabularies, and integrate archival and documentary sources [158]. The integration of primary data with scholarly objects such as research publications, support for aggregates, a semantic interoperability layer supporting linking between heterogeneous objects, and registries of research datasets, researchers, projects, digital services and tools were identified as important user requirements for more recent digital research infrastructures [154] such as those under development by DARIAH for the arts and humanities, and ARIADNE for archaeology.

Support for information integration and linking is, in fact, recognized as an important area of research activity in digital archaeology. As Nicole Beale points out, even “open data projects such as Open Street Map (Hagen 2011) have demonstrated that ownership of data can be regained by communities through the process of combining many datasets and creating something new”, quite like the added value of leveraging the geodata services of initiatives such as Pelagios to “remix” previously unassociated datasets [7], and, according to Kansa, the annotation of linked data with common ontologies [88]. Similarly, the work of Isaksen et al. on data from the Roman Port Networks Project aims to integrate them semantically in a single information system with the help of domain experts through “a prototype package targeted specifically at archaeologists that enables them to produce valid, globally-integrated RDF from unnormalized excavation data with minimal technical knowledge”, allowing archaeologists to map their data into a common schema [92]. The approach we developed at DCU and applied in the CARARE (Connecting Archaeology and Architecture for Europeana) and LoCloud (Local Institutions in an Europeana Cloud) projects, was based on providing automated and manual curation affordances to end users [184, 185], including the semantic enrichment (i.e., temporal identification, thesaurus enrichment, reverse geocoding and spatial translation) of heterogeneous XML schemas relevant for the representation and resource discovery of heritage data, using Metadata & Objects Repository (MORE) to curate records representing architectural and archaeological heritage assets and related digital resources aggregated for access through the Europeana digital library (<http://www.europeana.eu>) [186].

The development of curation-aware digital archives and repositories with semantic enrichment capabilities, and of registries allowing the collaborative integration and linking of information about researchers, projects, datasets and collections, schemas, and other relevant entities, demonstrates how epistemic and pragmatic curation processes can be supported within the custodial context of centrally curated, institutional information systems. It does not address, however, the pervasive practices witnessed in the Çatalhöyük excavation and other examples of archaeological practice, where information objects are curated from “the trowel’s edge” to online publication in a variety of settings, from the personal to the institutional. Such practices hinge on the capabilities of hardware and software tools that are, increasingly, offered by global infrastructures and services available to everyone including archaeologists, from capture devices in the trench to note-taking and reference management in preparation for archaeological publication. While a large part of the resources we integrated in the context of the CARARE and LoCloud projects come from institutionally curated archaeological archives, initial experience with aggregating metadata from social media services such as Wikimedia and Flickr suggests that, rather than depending on *ex post facto* curation after mapping and ingestion in a repository, it may be preferable to consider approaches to digital curation that upstream the process as “sheer curation” [140], supporting the tools and information management environments that users use in their primary context of work.

Significant further work is needed to develop a framework for the design and implementation of curation affordances that integrate semantic capabilities with an ability to operate across global, ubiquitous, and distributed infrastructures, i.e., bringing these capabilities to the devices, applications and other systems archaeologists are habitually using from fieldwork to online publication, education and public communication. Such work, aiming at reaching archaeologists and offering curation capabilities *in situ*, requires not just a realignment of technical focus from one area of development to another; it also entails a shift from a centralized, custodial approach aimed at the development of information systems according to a static specification to a decentralized, distributed, user-centred approach of flexible, reconfigurable and recombinant affordances available across personal devices and global systems.

## 6 Conclusion

The overarching research programme proposed in this paper concerns a two-pronged imperative of *representing and intervening* in the pervasive activity of archaeological curation in the digital continuum. My objective was not merely to identify a grand challenge for digital archaeology, but to illustrate its programmatic character, its articulation in specific, complementary, coherent areas of research activity,

and its potential contribution to the theory, methodology, and practice of digital archaeology. For this, I sought support from an examination of the looming curation crisis and emergent pervasive practices in the field of digital archaeology, an extensive case study of digital curation activities in the Çatalhöyük excavation, and an ontological model of archaeological digital curation that draws from cultural-historical activity theory. This attends to the interplay between underlying factors of agency, process and object, to represent the field of archaeological digital curation and to elucidate the relationship between an archaeological activity and related methods, procedures, digital tools and services, information objects, archaeological entities, underlying motives and goals, questions, project and research team.

The research program advanced in this paper is interdisciplinary, drawing from literatures of material culture studies, archaeological theory, information behaviour, archival science, digital heritage, and digital humanities. It relies on bringing together findings on curation practices in archaeological research work and “in the wild” with a formal account of research methods, specifications and actual experimentation on curation-enabled digital infrastructures, schemas and conceptual models for the representation of cultural “things”. The potential value of this research programme consists, firstly, in establishing interdisciplinary coherence between these dimensions, and, secondly, in contributing to: a) material culture theory, as it is re-examined in the light of contemporary archaeological practice (digital, post-colonial, participatory, etc.) towards an appreciation of the relationality and “thingness” of archaeological objects, seeking a third way between positivism and perspectivism; b) archaeological information systems and scholarly infrastructures, especially with regard to the integration of curation affordances (both automated and human), multiple and inconsistent representations of data with scholarly objects; and, c) archaeological digital curation, by focusing on its pervasiveness as practice (custodial, but significantly also “in the wild”), the objectual (infrastructural) inversion [187] instantiated by its systems and norms, and the ethical stakes involved in its research agendas and terms of engagement.

In his introduction, Huggett suggests that grand challenges for digital archaeology should be: a) fundamental with regard to the theory and practice of digital archaeology *qua* archaeology; b) innovative and consequential in scope, not just within but also outside the discipline; c) revolutionary in their ability to create new ways of knowing, and calling for radically new approaches, tools and techniques; d) inspiring and understandable by the whole sector, as well as by researchers in disciplines beyond archaeology; e) measurable in terms of objectives and outputs; and, co-operative, involving multiple, interdisciplinary teams and diverse potential solutions.

In light of the growing impact of pervasive, global digital infrastructures on everyday archaeological work, as well as on the increasingly contested regimes of archaeological knowledge production and meaning making, the development of a theory and pragmatic approach towards archaeological curation in the digital continuum, contingent on curation-enabled global digital infrastructures and on contested regimes of archaeological knowledge production and meaning making, is one hugely consequential such “grand challenge” for archaeology. Programmatic research on the nature and meaning of archaeological entities, on emerging archaeological practices “in the wild”, and on digital tools and services supporting archaeological “sheer curation” is necessary to meet this challenge. In the last part of this paper, I suggest particular approaches and solutions which mostly represent the work of my DCU colleagues and myself, primarily as starting points to initiate a dialogue with other research teams which will, hopefully, produce complementary, alternative, even opposed solutions and approaches. Meeting this grand challenge will require not only significant theoretical development and specification of pervasive approaches and functionalities for curation-enabled digital systems, but also extensive experimentation with building and studying such processes and systems of curation in practice. It will also require continued attention to the primacy of archaeological research activity, and to the intellectual development of a still fledgling field of inquiry – a reflexive, epistemic and pragmatic study of archaeological research practices and methods from the viewpoint of information, agency and meaning making.

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