# Balancing data storage and user functionality: the 3D and archaeological data strategy of the Tracing the Potter's Wheel Project'

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# Chapter 8
# Balancing Data Storage and User Functionality: The 3D and Archaeological Data Strategy of the Tracing the Potter's Wheel Knowledge Hub

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**Abstract** The Tracing the Potter's Wheel (TPW) project is designed to identify and assess the appearance of the potter's wheel as a technological innovation within the Bronze Age Aegean through the integration of experimental, analytical and digital archaeological approaches. A major output of the project is a technologically-focused archive that collates, presents and enhances research data about forming technology for archaeological and experimental ceramics. Another important project aim is to untangle relational and contextually-rich data storage for 3D models, with a particular focus on both metadata and paradata. Moreover, by disentangling the 3D models and treating them as an integrated part of the archive rather than a separately presented class, the project's active, multivocal knowledge base explicitly integrates the often-separated complementary perspectives on archaeological datasets, dubbed the TPW Knowledge Hub. To reach these divergent yet intricate objectives, TPW introduces the approach of designerly thinking into digital archaeological practice for the design of a user-focused interface to share information and knowledge with peers and the general public. Ultimately, the TPW archive serves as a dynamic learning tool uniting archaeological data storage with additional open-access publications and resources.

**Keywords** Reproducibility · Designerly thinking · Knowledge base · 3D models · Multivocality

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## 8.1 Introduction

Tracing the Potter's Wheel (TPW) is a five-year research project funded by the Dutch Research Council (NWO). The project is designed to identify and assess the appearance of the potter's wheel as a technological innovation within the Bronze Age Aegean (2500–1200 BC) through the integration of experimental, analytical and digital archaeological approaches. A major output of the project is an archive which captures and shares technologically-focused information about forming techniques for archaeological and experimental ceramics. From the outset, the project archive was designed to assist and enhance project research while simultaneously sharing data and knowledge with peers and the general public. In this light, the TPW archive has been designed as a dynamic learning tool which marries the stable storage of digital pottery information with a user-focused interface, complemented with additional open-access publications and resources. The project has also grappled with designing relational and contextually-rich data storage for 3D models and their associated information, particularly both metadata and paradata. 3D models are treated in this approach as an integrated part of the archive instead as a separately presented class. This diverse approach to data storage, knowledge and learning has coalesced into the TPW Knowledge Hub. The design and functionality of TPW's active, multivocal research knowledge hub is worthy of further discussion as it explicitly integrates these often-separated complementary perspectives on the archaeological data.

## 8.2 Taking Up Challenges and Forging Strategies

A number of specific challenges exist in relation to the Tracing the Potter's Wheel Project's goals for creating a stable and user-friendly repository of pottery records. These included the nature of the data types the archive is composed of, the interest in being guided by design thinking, and the project's understanding of the nature of a 'common vision' in pottery archives. Design thinking has a different approach from the usual problem-solving technocentric approach. Instead, it revolves around the idea of problem-finding from a human-centered approach (Clarke 2019, p. 13), seeking to locate the needs and understand the issue in the system that users are struggling with before then solving the technical problem. In other words the developer never starts with the solution, but starts "determining what basic, fundamental issue[s] need to be addressed" and then "consider[s] a wide range of potential solutions" (Norman 2013, p. 219). Design thinking consists of a series of challenges, some exciting, others more of a drawback, that also form opportunities as well and which occur within a social group. The design process can be divided into iterative but non-linear, reflexive phases. These phases include, but are not limited to: understanding the data types and users (visualised through a data wireframe, for example); observations of the circumstances (through comparison against other archives and platforms for data models and user experience); functionality assessment; prototyping (through which several designs are developed); as well as the actual building, testing, and launching of the database. This multifaceted approach to problems, or challenges, is a creative practice. A key benefit of this iterative process is that, when practiced in a transparent and coherent way, it can be applied by others and developed accordingly (see also *Ideo*).

In order to develop the archive platform, TPW sought the partnership of commercial developers, funded by a Dutch Data Archiving and Networking Service (DANS) Small Data Project grant (Klein Data Project, KDP). TPW's partners at KBELL & POSTMAN (https://kbellpostman.com/) employ a *design thinking* approach from a creative, user-oriented perspective, modelling and modifying from experiment and experience with a wide range of users. Within this partnership, the TPW team takes an academic stance, just as scientists take a more formal strategy towards problem solving, the goal of which is to learn from these attempts (Sarwar and Fraser 2019, p. 345). This is perhaps more properly called *designerly thinking*, which "links theory and practice from a design perspective" (Johansson-Sköldberg et al. 2013, p. 123). This leans more to the 'layers of design' practice as formulated by Lawson and Dorst 2009 (Dorst 2011, p. 526), which is focussed on project, process and 'field' (Bourdieu et al. 1999, cited by Dorst 2011, p. 526), or social context. The latter stands for a more deliberate way of reasoning in which diverse social groups are taken into account. Furthermore, it reflects on project-specific methods of data collection as well as the way that data is disseminated as meaningful archaeological information. Through the archive, knowledge is produced while mechanisms of receiving new data and knowledge from other disciplines are nurtured. This collaboration between commercial developers and academic researchers working under the umbrella of design thinking is very fruitful in the development of a dynamic archive that suits the project and a wide range of targeted users.

The agile and particularly reflexive approach that design thinking can bring to archaeological practice is not restricted to the digital realm alone: problems such as data uncertainty already exist in the practice of collecting, recording and digitisation. The choice of what data to collect, what research is deemed interesting and informative in the first place (and which is negotiated over time, as argued by Börjesson and Huvila 2018, p. 14) is the basis of a database structure, and furthermore has an impact on archaeological knowledge-making. The first problem is encountered in the collecting phase: the ambiguous nature of archaeological data, being often fragmented and incomplete. Fragmentation and incompleteness are not appreciated in creating data models. Further, uncertainty about an object's specific forming method or a precise chronological date is hard to capture within a database model, let alone to query (Piotrowski 2019). Another frequent problem arises when data is collected under different circumstances and through different strategies, which can lead to inconsistencies in data patterns and resulting data accuracy. And although most data in the TPW project has been analysed and collected by the project members themselves, some data depends on archival data produced by other specialists that was recorded differently, impeding comparability and reproducibility (a pitfall described by Boast and Biehl 2011, p. 128). These inconsistent datasets are then difficult to compare, resulting in uncertain outcomes. TPW has overcome this problem by forging a strategy for the selection and recording prior to digitisation and manipulation, or 'data context' (Huggett 2020, S12), which was applied during fieldwork and at diverse locations (see Fig. 8.1). This overarching strategy steers the selection procedure, description and photographic procedure, the standardisation of equipment, and 3D recording procedure and related metadata standardisation for the analogue and digital recording processes. Many potential data uncertainties are prevented by this consistent strategy. It should become apparent during the planned later phase of the database, when other specialists and projects begin to contribute a dataset to the TPW archive, that following the same selection, collection and digitalisation procedure is crucial. In this way it is possible to safeguard data accuracy, meaningful re-use and assembly of data and subsequent comparative analysis that form the basis of archaeological knowledge production.

Over the course of fieldwork and analysis, TPW has generated considerable data, composed of multiple file types for images, video footage, 3D models, and texts, as well as the contextual information for those files, including metadata and paradata. This large volume of data is, in fact, representative of a relatively small number of archaeological and experimental objects. But each object included in the database has its own solar system of associated data files which provide different perspectives on the object represented. Taken together, these many solar systems of data files, create a galaxy of relations between the objects. Although the objects studied are not the totality of the objects from any one site's ceramic assemblage, by capturing information about objects scattered across the universe of an assemblage, it is possible to understand some of the key features of that universe. These data represent a multiplicity of complementary perspectives on the objects themselves. In effect, data was collected in different formats to gain different insights into the nature of a number of specific archaeological and experimental pots (see Fig. 8.2). This challenge was an important one to meet, because the value of making such an archive is the presentation of this complementary information in its context; file types need seamless interconnections to illustrate different points. A major difference between this archive and others is the integration of 3D models alongside other types of object representation; presenting all these different file formats side-by-side is essential for illustrating the complexity of that object. Additionally, this project does capture and present information about different kinds of pottery. The specific needs for presenting an archaeologically-retrieved object are different from presenting an experimentally-produced object and, as such, the kinds of information which populate the context also differ.

## 8.3 Current Solutions for 3D Models in Archives

Today, digital 3D technology is applied in virtually every sub-discipline to document, analyse and (re)present archaeological data and heritage. Many archaeological 3D datasets are now available online and are often held up as examples of the

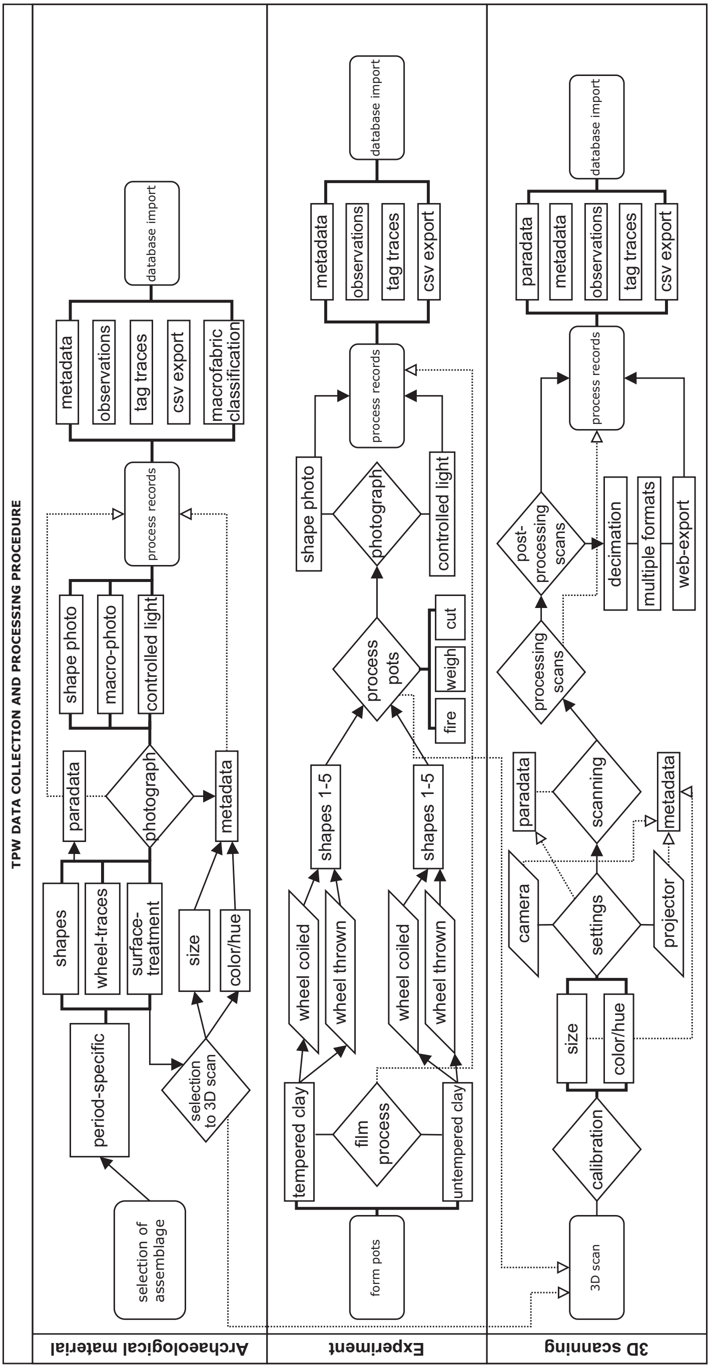


**Fig. 8.1** Diagram representing the data collection and processing procedure. (Image: L. Opgenhaffen)

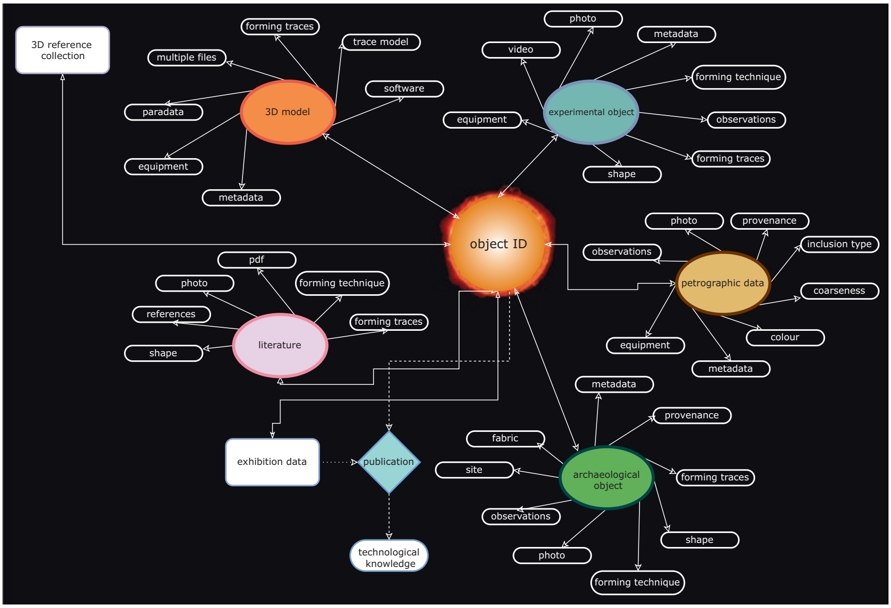


**Fig. 8.2** TPW data types, data and metadata contexts represented as an interconnected constellation orbiting the object ID. (Image: L. Opgenhaffen)

democratisation of data and knowledge production. However, the standard varies considerably, as revealed in an exploration carried out by the TPW team into 3D repositories and online pottery archives. Our observations support the results of a thorough survey of '3D' digital heritage repositories and platforms by Champion and Rahaman (2020), and the study by Statham (2019), which offers a comparative analysis of several 3D platforms and their relation to prevailing international guidelines for preserving heritage (ICOMOS and UNESCO *and* the London Charter and Seville Principles). Few of these platforms have significant user participation or even interactive tools, nor do they have the possibility to annotate or contextualise the 3D content. Actual engagement by users through interaction with the model for topography or stylistic exploration, or by interrogating the underlying data – functionality for comparing 3D models (also with other media) and allowing comments or contribution of similar datasets – are virtually absent in these repositories. The democratisation seems therefore to take a one-way direction.

### *8.3.1 Digital Archives and Platforms*

An increasing number of pottery databases are appearing online, which is a positive development. While in the early years of digitisation pottery archives tended towards a digital replication of a traditional catalogue (such as the Beazley Archive), an increasing number of initiatives aim to move beyond mere cataloguing and provide active repositories supported by rich media, tools to compare and study objects, and semantic searches. These projects, such as ArchAIDE and the Levantine Ceramics Project, have rich databases and appealing, clearly structured websites. ArchAIDE in particular has easy search functionality, associated vessel display, and has integrated 3D models with accompanying metadata through 3DHOP, and a tool to automatically identify pottery shapes. Other promising online platforms for pottery identification, 3D visualisation and comparative analysis were the *Pottery Informatics Query Database* (PIQD, Smith et al. 2014), that aimed to go beyond digital archiving and presented itself as online, open-source tool to automatically extract data from scanned potsherds and provide rich (3D) contextual information. In 2015 it joined the CRANE project, after which it withered. Another platform is the EU funded project GRAVITATE-EU, which is building a digital platform that offers tools for reassembling fragmented material, shape analysis and comparative analysis based on 3D geometry and semantic data. A brief survey of online pottery databases leads to the conclusion that, besides some promising platforms as mentioned above, the level of data literacy, especially when it comes to visualisation and user experience, is markedly low. Indeed, it seems that these two concepts are fundamentally linked: if visual files are not immediately accessible and only lists of information are visible, then records are usually only accessible to specialists, due to reduced searchability and potential for comparative analysis. In this sense, these websites have poorly-considered design, which leads to reduced navigability and often prevents non-experts from querying the database. Another function which is often lacking is annotation of the 3D models, which improves their contextualisation and searchability, but is also critical for accessibility and comparative analysis, for specialists and non-specialists alike. Lastly, very few websites allow for comments on their data (however, The British Museum online catalogue is one of the few to allow this function), another important element in stimulating comparative analysis.

Pottery, and especially past potting practice, seems not to be the first choice for constructing and testing versatile 3D archives. A strong focus on disseminating research and cultural heritage in 3D is in excavation, architecture and 3D documentation of special finds. Good examples of digital archives with embedded 3D viewers include Dynamic Collections and 3D Icons Ireland. The former uses 3DHOP to visualize, annotate and query artefacts from a reference collection, with familiar tools to the archaeologist such as lighting, measuring and sectioning, and to freely rotate the object. The system serves as an excellent complementary learning tool alongside the physical collection and has the functionality that allows students and other stakeholders to create their own collections, and to tag and make notes in an on the artefact, which can then be saved and shared as a json file (Ekengren et al. 2021). The latter project uses Sketchfab as an embedded viewer in a data structure that reads as an article, accompanied with other media. This narrative presentation of archaeological data common to projects is beneficial for users who might be unfamiliar with specialist catalogues and lists of raw data. This can be compared against the presentation of the Cinema Parisien in 3D reconstruction, carried out by researchers working within the framework of CREATE (University of Amsterdam). This 3D reconstruction is presented in reasonable quality using the Unity web player and is successfully connected to the database, which enables to request its underlying data (text and images) by freely clicking on any part of the building while walking through the movie theatre. Further, users are given the option of leaving comments (see Noordegraaf et al. 2016 and *Cinema Parisien*; this web application works only with Waterfox and the Unity Web Player).

One example of a digital archive that does focus on potting practice is the Collections de la technothèque, an initiative of the Laboratoire Préhistoire&Technologie (PréTech, UMR 7055, CNRS / Université Paris Nanterre) to open access to the rich research material collections of the experimental and ethnoarchaeological repositories for prehistoric techniques (where the experimental ceramics of TPW member Caroline Jeffra can be found (Jeffra 2011)). Although there are no 3D models within the repository of ceramic forming techniques, their objective in allowing the public to consult their collections remotely, according to their level of interest, mirrors the goal of the TPW digital archive. A final mention should also be made of the ARKEOTEK organisation and associated online journal, which partners with PréTech to provide "un accès en ligne à ces collections référentielles qui constituent d'indispensables outils d'expertise" [online access to these reference collections, which constitute essential tools of expertise] (*PréTech*). Although it does not support 3D content, nor does it have a multivocal aim in addressing lay audiences, the core objective of ARKEOTEK was to create a knowledge base centred on the 'archaeology of techniques'. Here, experts share their research through the publication of not only datasets and results, but also the reasoning processes built upon them (Gardin and Roux 2004, p. 29), based upon the Scientific Construct and Data (SCD) format designed by Philippe Blasco. This practice-centred perspective is further elaborated by Dallas, who maintains the importance of not only the research dataset but also "processes related to the production of knowledge, its public communication and user experience in digital curation" (Dallas 2015, p. 192). It is this orientation which has informed the foundation of the TPW database.

There are few nationally-funded initiatives for managing this type of research-driven 3D data. One notable exception is the Archaeological Data Service (ADS) which has an embedded 3D viewer similar to 3DHOP (the same developers are behind it). ADS provides a highly detailed metadata-scheme (available via *ADS metadata scheme*) to record data-retrieval, postprocessing and technical specifications. Furthermore, ADS does not treat 3D data as a separate class or collection; rather it is integrated into the repository with an impressive level of flexibility in how a project can choose to present their 3D data.

On an international level, Europeana provides a platform on which European cultural data is displayed (but not hosted). By engaging with wider-ranging efforts such as these, there is less risk for projects of falling into obsolescence. Europeana does not support 3D content itself, instead relying on embedded viewers such as Sketchfab. Another supported format was 3D PDF, a promising format a decade ago but, as Flash is no longer supported, the 3D content can no longer be navigated online. For 3D models, Europeana has now the app Share3D (available at https://share3d.eu/, not to be confused with Share3D.com) to link Sketchfab models and submit (limited) metadata to Europeana. In the dashboard, the metadata can be adjusted to Europeana standards, though these standards are not directly accessible, as entries must be shared with Europeana via an approved aggregator. In the case of archaeological material, CARARE is Europeana's designated aggregator. This is a suitable solution if projects have few 3D models, but with larger 3D datasets this cumbersome pipeline of Share3D can be a huge and laborious task. Furthermore, the services provided by many aggregators incur yearly costs, an issue which has repercussions for the long-term sharing of data beyond the life of temporary projects.

With the exception of rare examples such as those described above, 3D models are still most often set apart as a visual data class, presented apart from other contextual data in '3D collections' within projects and project databases. 3D datasets should not be presented in isolation, and solutions must be crafted which integrate 3D models within archives while giving due attention to user experience of those archives. A 3D model only becomes a meaningful visualisation when embedded within its contextual information. Projects which fail to recognise this risk returning archaeologists into object-focussed antiquarians.

## *8.3.2 Viewers: Sketchfab and 3DHOP*

A significant technical hurdle to fully integrating 3D models within a user-experience designed archive is the limited range of available viewers for embedding and presenting those models. The TPW Knowledge Hub is not exclusively a 3D archive presenting an exciting 3D collection, instead it is an archaeological narrative about past pottery technology and social interaction in which the 3D models are an integral part. For this reason, the 3D viewer must integrate seamlessly with other types of data presentation, allowing interconnections with those data and their corresponding file types. A number of essential functions have proven useful for including models within the archive. These include tagging and presentation tools, embedded analytical tools, and easy download options. These functions play an important role in allowing users to more fully interrogate the material based upon their observations in the models and other media shown alongside them.

### 8.3.2.1 Tagging and Presenting Models

A 3D model is not self-explanatory; tagging functionality embeds a 3D models contextual information within the model itself, rendering it a meaningful object. In doing so, tagging enriches the model and makes it a meaningful scientific representation of archaeological knowledge. Yet, the diversity of tagging and presentation needs for the field of archaeology may make it resistant to standardisation; it depends heavily upon the aims of the visualisation, which can be a 3D model of a

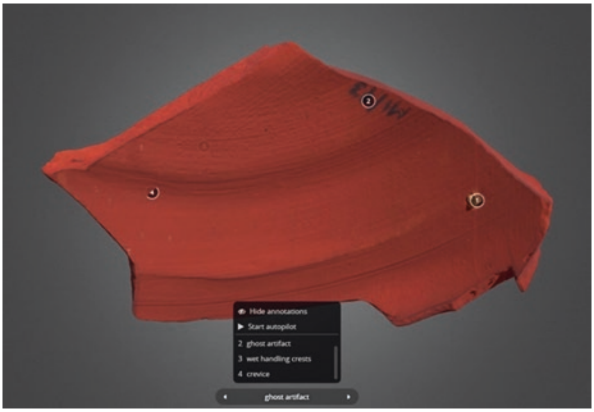


**Fig. 8.3** Example of an annotated 3D model revealing information about both forming traces and 'ghost artefacts': https://sketchfab.com/3d-models/m1-73-002dec-676cb1d9ae11431498544a98911d97bb

monument, a multilayered excavation, or fragmented artefacts. Tagging also depends on many other related factors, from recording to presentation, and even teaching.

In the case of research in pottery forming technology, tags provide targeted description of specific model attributes, both relating to the data collection process as well as the morphology of the object being visualised. For example, TPW's SketchFab models often indicate the presence of forming traces, such as crevices, alongside 'ghost artefacts' such as inward-projecting surface topography on a model where the physical object was darker in colour (Fig. 8.3). Tagging furthers the aim of integrating models alongside other methods of data presentation (such as text, photographs and video). Sketchfab achieves this by providing user-friendly tagging functionality which can include links to related data, texts, and media within the database and to other websites. This enriches the model, making it informative and giving it a meaningful voice. Users can be guided in what to see and thus be informed, in the TPW case, about forming traces. In comparison, 3DHOP's tagging functionality is significantly less user-friendly, as the 'hotspot' needs to be assigned in the code, a time-consuming task which is beyond the skill set of many archaeologists.

#### 8.3.2.2 Analytical Tools in Model Viewers

There are a number of analytical tools which archaeologists use when directly handling objects, and some similar functionality is available for interacting with 3D models. Sketchfab's most archaeologically-useful analytical tools are the matcap function in the model inspector, which enables turning off the texture, and the directional light tool, which both enable to inspect morphological features in more detail. It does not have a measuring tool, however, and a sense of scale is only possible if a scale bar is uploaded with the model. 3DHOP, on the other hand, provides a toolkit that enables detailed simulation of the physical analysis workflow. This functionality includes a torch to illuminate specific parts of the object, an option to turn the texture off, a measuring tool, and the possibility to make sections on different planes. The familiarity of these tools, and the expansion of functionality of matcap or texture removal, strengthens the case for using these viewers for research that enables study of objects which better approximates direct handling of these objects.

## 8.4 The TPW Pottery Archive

A wide range of online platforms are available, both with and without 3D content, which gives ample opportunity for researching solutions to fit the needs of the TPW Knowledge Hub. This diversity was both motivational and inspirational during the design process, informing the project on avenues to avoid specific problems in data representation, as well as how to address multiple audiences and user needs. Through this research, the need for a tailored solution became clear. Although not currently supporting 3D data, the DANS Small Data Project grant awarded to TPW enabled the project partnership with developers KBELL & POSTMAN for the design of an active archive to be hosted by the University of Amsterdam. These experienced developers give an unique insight into user experience processes beyond the borders of cultural heritage, inspiring TPW to engage in more designerly thinking and reflect on the processes within the project in a more creative way.

As highlighted above, a major difference between the TPW Knowledge Hub and others is the integration of 3D models alongside other types of object representation. Each of the file types, and the types of objects described in those file types, have different metadata needs. Although metadata standards for cultural heritage exist in data models such as Dublin Core and CIDOC CRM, these do not specifically incorporate 3D content needs and requirements. The most important problem in these data models is that there is no clear definition of what kind of entity a 3D model is exactly and how to label it (for an interesting example of such confusion can be found at the CIDOC CRM Issues section: http://www.cidoc-crm.org/Issue/ID-342-3d-model-example-in-p138), and no system to record the metadata of a model yet, although CIDOC CRM is currently developing the CRMdig ontology and RDF Schema to encode metadata about digitisation processes, both 2D and 3D (http://www.cidoc-crm.org/crmdig/). CIDOC is quite prescriptive rather than descriptive, which makes it inflexible and hard to apply in a diverse discipline as archaeology, with divergent (national and institutional) recording and documentation traditions. It proved extremely difficult for TPW's domain-specific pottery manufacturing traces and fabrics classifications to adjust to CIDOC. The Dublin Core is less extensive than the CIDOC CRM and thus more flexible for specific collections and specialisms, while the principle classes are compatible and therefore findable. A final example is the CHARM reference model, a semi-formal abstract reference model with a wide range of different users. CHARM is not prescriptive about too many details; users should define their own particular properties within this data model by using extensions based on 'object-oriented conceptual modelling principles' (*CHARM*).

Clearly, work remains to be done to translate these models into domain-specific language for more ready application to archaeological materials, particularly in the case of smaller projects who may not be able to outsource this important aspect of sharing their data. In order to prevent reinventing the wheel, the TPW model will adhere, where possible, to the CIDOC CRM framework while building forth on the concepts of the CHARM model. This approach to data combines prescriptive with descriptive models that will suit our research objectives, contributors and user's needs, and enables planned integration with Europeana.

The 3D models in the TPW database are classified as a piece of data relating to a physical object. The simple solution is to link the 3D model in the database via the object ID used for the original, archaeological or experimental, object. With that ID, the model will be automatically annotated and linked to its contextual data. This resolves the risk of isolating the 3D model while also preserving the visibility of the technical metadata and paradata about the choices of the archaeological visualiser. This paradata is captured in the workflow description for the entire scanning, processing and post-processing procedure, including choices for particular hardware and software, their settings, as well as parameters such as the decimation algorithms to simplify the models. This workflow is published on the project website (Opgenhaffen 2020a), and video tutorials about specific scanning solutions are in production. This transparency in project workflows and data collection procedures are created with the FAIR principles in mind. TPW values these guiding principles to ensure transparency about data and methodology (Opgenhaffen 2020b), and to keep the data accessible and discoverable at all times (Wilkinson et al. 2016). Moreover, tutorials about workflows and the availability of rich metadata schemes enable the possibility to reproduce data collection and sharing, and to reuse data to increase knowledge about transmission of ancient technology.

TPW is currently using Sketchfab Pro to share and publish the 3D models of the experimental dataset (see Fig. 8.3). Although 3DHOP has better functionality for archaeological inspection, Sketchfab works faster in uploading and tagging the models. Despite Sketchfab being a commercial platform, the Pro version is free of charge for educational institutions. Sketchfab Pro enables models up to 200 MB to be uploaded, which ensures a high degree of geometric data integrity, that is, not too much data is lost when decimating/simplifying the raw files to an acceptable format and size for online display. Indeed, TPW is well aware of the issue of ownership in the case of a profit-oriented enterprise such as Sketchfab, and so hopes to overcome this in the near future through an in-built viewer. The Sketchfab models are embedded in the web interface, and the different file formats of the 3D model are provided as download files, such as the original scandata, the exported OBJs and simplified OBJs, PLY and STL files. Together with the technical metadata and detailed workflow description, the transparency of the entire workflow from scanning through to file processing is guaranteed, as are file compatibility and reproducibility of workflows. The ability to reproduce workflows and reuse original files ensures a

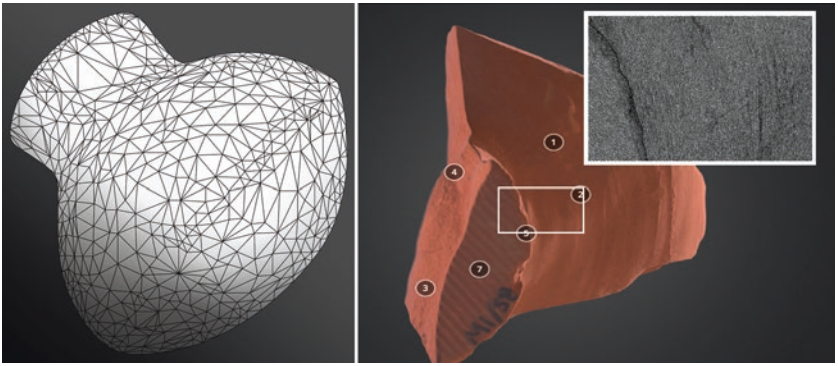

**Fig. 8.4** Left: a 3D scan made in 2002 (after Rowe et al. 2002, Fig. 8.1). Right: a 3D scan made in 2018. (Image: L. Opgenhaffen)

consistent accuracy of data quality. Downloads also enable users to conduct further offline analysis, as well as to compare 3D models of artefacts in open source software such as Meshlab. In particular, the 3D models of individual forming trace examples from the unique reference collection developed by TPW can be downloaded and 3D printed to function as a physical training set. Users can then inspect the traces in a tactile way, achieving a better understanding of pottery technology alongside the digital material showing greater contextual information.

An important issue, however, is whether it is possible to maintain the ideal of reuse, reproducibility and data assessment, given that ever increasing scanning resolutions and computing power regularly render hardware and software obsolete. This means the safeguarding of the contextual data is extremely important, as the hardware and 3D models can always be replaced. As an example, 3D models of pottery recorded in the early 2000s, consisting of a few dozen faces, are impossible to compare against 3D models of the same pots made today, which consist of a few million faces (see Fig. 8.4). Similarly, early 3D models do not have the level of detail that is required to identify particular manufacturing traces. Replacement of an early 3D model with a modern 3D scan produced according to the current recording strategy enables a detailed topographical analysis while maintaining the contextual data that was originally documented. The same procedure can be repeated in another two decades.

### *8.4.1 Archive Architecture*

The relational database is built with MySQL, and the platform with PHP (8) on top of the Laravel (8.0) framework. Laravel is a popular open-source PHP-framework providing scaffolding for web applications. This enables modular packages to be built on top of it to manipulate and maintain a web interface while running several applications. This, for example, allows for multiple data sources to be visualised while embedding external viewers. The platform is powered by the search engine Algolia to improve search results and especially ease search queries. It adds a search box to the website front end and supports simple text-based search approaches. As it indexes the TPW site, Algolia offers web search experiences comparable to Shopify webshops, which enables users looking for forming traces of pottery on the internet to find the information in the TPW database more easily and faster.

### 8.4.2 Static vs Active

From the outset, the TPW Knowledge Hub was designed to facilitate future research into pottery forming techniques. Given the sheer scope of such research, not only in the Bronze Age Aegean but also in regions and periods beyond our TPW remit, it was acknowledged early on in the project that the archive might be supplemented by other reference collections in the future, to consolidate the known repertoire of surface macrotraces that relate to specific forming techniques. As a result, the project aims were adapted to create the foundations for a dynamic knowledge hub of wheel-formed pottery that could be extended to increase knowledge about past potting technology and technological transfer thanks to cutting-edge digital technology. Such functionality requires an archive that can be *actively* added to, or updated, through the inclusion of new datasets, which goes well beyond existing frameworks for archiving datasets. DANS facilitates the deposition of complete datasets, or static archives, with the capacity for a limited number of iterative updates and where each iteration is assigned an individual DOI. This situation appears overly reliant upon models for digital archiving of written text and ignores the dynamic opportunities that a more active archive can bring to researchers. The benefits of digital data repositories, whether static or active, allow information to become openly available and accessible, creating opportunities for re-use of that dataset in subsequent research. Perhaps as a result of the DOI attribution system, there is as yet no potential to create a digital resource that can be continuously updated, such as a repository/archive that has the ability to accommodate the research input of multiple teams/sources working towards a shared research goal. For this reason, TPW will deposit material into a research archive with DANS as a *static* archive in early 2021, as part of their Small Data Project incentive scheme. But in "an ideal data lifecycle", as Kansa Whitcher and Kansa (2014, p. 225) put it, an archive should not be a "final resting place" for data. Indeed, the authors believe a dynamic archive, one in which resources are updated as new research is undertaken, is an important part of communicating and contextualising research. By increasing opportunities for research collaboration, both present and future, the TPW project better fulfils its societal impact goals and moves closer to building new knowledge about the innovation of the potter's wheel. Therefore, the web portal to the *active* repository with a sophisticated back end will be hosted and maintained by the University of Amsterdam, enabling continued knowledge exchange between peers and the public.

## 8.5 Knowledge Transfer and Learning Pathways

An important component of the TPW Knowledge Hub which was identified early in the design process is the integration of learning pathways to facilitate knowledge transfer (for more information about the concept of learning pathways, see Hilditch et al. 2021). With the knowledge that potting technology assessment is a growing field which all too often depends on extended periods of in-person object study, TPW sought to create solutions which could widen participation. Furthermore, many digital archives are designed for use by well-experienced users who have deep pre-existing knowledge of the field, which excludes participation by students or the general public. The solution pursued by TPW is the creation of resources to orient users in terms of how to use the archive, as well as how to perform data collection and analytical tasks presented within the archive: in effect, facilitating non-specialists into becoming partially specialised users.

Tutorials and other kinds of learning tools guide users through the database, which are tailored to their level: specialist, student or general public. These tutorials not only inform on topics such as how to use the archive or a structured light scanner, but also allows knowledge transfer relating to a number of topics including recognising wheel-forming traces, new insights in ancient technology, the role of 3D visualisation in archaeological practice, and 3D models of heritage objects for the mobilisation of knowledge transfer. The reference collection of wheel-forming traces is the visual portal where the investigation of potting technology begins. A trained specialist can readily dive into the details by browsing further through the displayed contextual items, or by a targeted search. At all times, video tutorials and explanatory blog posts are easily accessible to help guide the user from superficial to complex exploration through the data. Students, as well as the general public, can start with the visual representations in the main view port. These may either be detailed photos of fabrics and vessels obtained by targeted light photography (for which the metadata scheme and how-to DIY manual is also available) or 3D models (for which workflow tutorials and metadata schemes are available). Both photos and 3D models are tagged so that the forming traces are recognisable, and these tags contain links to further explanations. A multitude of different file formats of the 3D models are made available to download, and a dedicated part of the reference collection has models of single macrotraces that can be downloaded for 3D printing. This unique training set enables users to tangibly explore traces of forming techniques, as a tactile survey of the surface is an essential part in the process of identifying forming techniques that cannot be replaced entirely by virtual technology.

The clear research objective-directed database risks the creation of so-called 'filter bubbles' which affect data retrieval and use through the application of particular search tools, and especially impact the structure of the data (Huggett 2020, S12). The easy access and functionality ideally democratise the use and re-use of data that could contribute to new knowledge and shaping narratives, but the simplicity of these tools inevitably channel this shaping in a certain direction. However, as long as this risk is acknowledged, and transparency about research aims is maintained, this directional shaping is not necessarily an un-democratic approach. Project data was collected for wider communication of past technological changes, as well as how to recognise features indicative of those technologies. The archive also provides recording strategies that maximises reproducibility and ensure comparability between datasets. In this respect, a fluid and flexible re-assembling and re-use of data in an unguided and 'free' way could lead indeed to interesting new interpretations by 'local stakeholders' and third parties, but whether this truly produces new scientific knowledge is debatable.

## 8.6 Summary

Some challenges and solutions for presenting and curating 3D data alongside other types of archaeological data have been briefly introduced here. The 3D models captured by TPW form an integrated part of the multiple datasets represented by diverse media and file formats presented within the database. Overall, the web-based archive democratises interaction with archaeological knowledge by opening access to specialised archaeologists, students, and non-specialists alike.

The question remains, however: how can we establish a sustainable repository that actively fosters further research by future users? 3D models are exceptionally useful as a means to simulate and stimulate intensive object study in the field or lab, a point which is reinforced by thoughtful creation of storage and access solutions. The TPW project has ensured that its datasets have met the basic requirements of sustainable archiving, such as catering for data quantity and format, open access, and adequate infrastructure for long-term storage. However, these basic requirements, which many other projects are also currently meeting, do not necessarily foster strong interaction by users. On top of this, the commercial platform Sketchfab is dependent upon an economic profit model, whereas 3DHOP requires the continued investment of the Italian state and the European research framework, risking accessibility of the 3D models in the long term. Lastly, 3D models remain at present a volatile format, in which their accuracy relies upon the standards of ever-changing current technologies. Taking all these uncertainties into account, it is imperative that the contextual data making the 3D model meaningful should be stable, sustainable, and accessible at all times. For now, TPW seeks to exceed the requirements within existing data frameworks by depositing our data with the Dutch national digital data repository DANS, and by listing the objects on Europeana soon afterward.

The TPW team sought to push beyond balancing between stability and usability by supplementing the deposition of datasets with a custom-built, user-friendly web-based database, and has forged a strategy where integrated data management meets known project objectives (see Fig. 8.5). The TPW Knowledge Hub will promote learning processes for recognising wheel traces, and provide structured 'on boarding' or familiarisation for data collection techniques through manuals, learning pathways and guidelines.

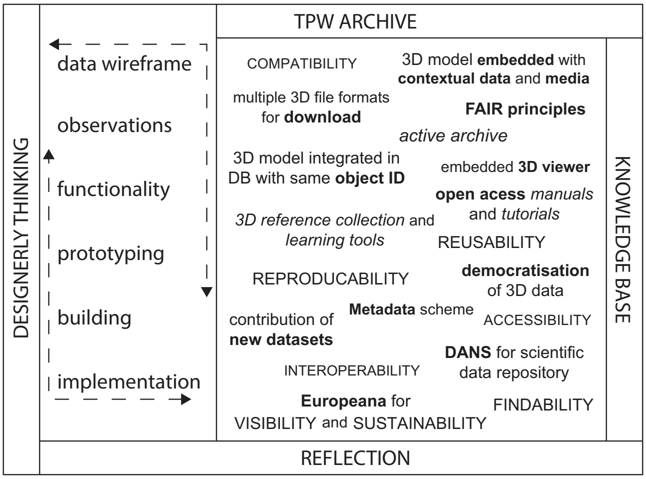


**Fig. 8.5** Summary of TPW's workflow, *outputs*, **primary aspects** and GOALS in creating the active archive. (Image: L. Opgenhaffen)

## 8.7 Future Directions

One of the project aims has been to stimulate research into how potter's wheel technology spread across the Aegean over time. A remaining, major task now is to advocate for others to make use of, and ultimately contribute to, this Knowledge Hub. This involves training other specialists to recognise and interpret evidence for pottery production technology, as well as encouraging gathering of further data on this topic. Potential users of the Hub can be reached by presenting in specialist sessions on digital (3D) pottery archives, but widening engagement with general users must also be achieved through other means, such as interactive museum exhibits and online activities. By using a simple embedded viewer with integrated features alongside the wider contextual information of TPW datasets, and enabling multiple download files, the 3D reference collection has a special role to play in helping users to transition into the role of a specialist in an interactive and even tactile way.

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