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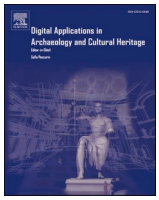

Archives in action. The impact of digital technology on archaeological recording strategies and ensuing open research archives

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ABSTRACT

Digital-born research archives, data re-use, participation and the inclusion of academic and lay stakeholders in archaeological knowledge production. These are important topics that are increasingly addressed but often overlooked in the creative stages of archiving, be it data collection or the reproduction of an archiving practice. This creative practice is affected and changing due to the implementation of digital technology. These practices are reproduced in the design of the research archive and, as such, the impact of technology can potentially be scrutinised and traced reversely by analysing the uses of the archive. In addition, digital technology is believed to prompt greater inclusivity of diverse audiences. But how to reach that audience, and who is this "audience"? In this paper, emphasis is placed to reflect upon the practice of archiving of ongoing, post-excavation archaeological research with an audience, as opposed to well-established reflexive research into excavation and museum practices. As such, the concept of archiving as research process, rather than the traditional approach towards archives as data repositories is introduced here. As a case study to identify and assess potential change in a particular archaeological practice, the paper describes and analyses the archiving practice of the team of the *Tracing the Potter's Wheel*-project, from its inception in offices and storerooms to the archive's targeted manifold use as a place of knowledge production, data sharing and learning.

1. Introduction

This paper contributes to the academic debate concerning the application of 3D modelling of cultural heritage by placing focus on the reflexive and methodological approach of research practice, tools and techniques used in the creative process. The ongoing research project *Tracing the Potter's Wheel* (TPW)[1] and its resulting project archive the *TPW Knowledge Hub* is taken as a case study to illustrate the practice of creating and facilitating the multiple uses of diverse audiences of an archaeological research archive. The team of the TPW project is composed of an experimental, a digital (the author) and a science-based archaeologist who collaborate closely together to study and identify technological trajectories in the Late Bronze Age Aegean. The introduction and uptake of the potter's wheel, as technological innovation in existing production practice, is used in this project to trace such technological processes. The digital 3D visualisation of archaeological ceramics takes an integral part in the project, and while investigating ancient practice, archaeologists' own practice and dealings with new technology, comes to the fore as well. In this present practice, 3D recording is part of a larger process of collecting, documenting, archiving and sharing of archaeological data in a research-driven digital archive. In this archive, the TPW Knowledge Hub, users can contribute, analyse and re-use not only archaeological data such as photographs, videos, 3D models and textual data, but also metadata including tutorials on how to use 3D scanners to record certain categories of archaeological objects, in this case wheel-fashioned ceramics. These 3D workflows can then be applied in other projects, in order to increase comparison between datasets.

Subsequently, the analysis of archaeological archiving practices may then be compared with previous, analogue recording and documentation practices. Archiving is here understood as not only the moment of deciding which research data is archivable, but as a practice of the selection of archaeological objects to study, and the subsequent process of recording the objects with different tools and the documentation of this process, which is archived with the object as well. To what extent has the practice, despite the application of digital tools, significantly changed? Similarly, digital technology has enabled both expert and non-expert audiences to become engaged in archaeological knowledge-making at

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[1] The Tracing the Potter's Wheel-project is a 5-year research project funded by the Dutch Research Council (NWO), directed by Dr Jill Hilditch. The present paper is part of a PhD project carried out within the TPW project. For more information about the project, visit https://tracingthewheel.eu/.

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the lab and the trench, and interpretation "at the trowel's edge" (Berggren et al., 2015; Berggren and Hodder, 2003), rather than unilaterally presenting a package of conclusions at the end of a project. But has this multivocal approach in archaeology also impacted choices in the deployment of particular digital technology, database organisation and interface design, and collection and recording procedures beyond the realm of excavation or built environments (for reusability and re-use of field data, see for example Strupler and Wilkinson, 2017)?

Over the past 25 years, reflexive practice as promoted by Ian Hodder (Berggren and Hodder, 2003; Hodder, 1997, 2003, 2005) has resulted in a growing awareness of archaeological praxis, the technology used in outreach activities, and an increasing number of studies are dedicated to these issues (for example, Berggren et al., 2015; Lukas et al., 2018; Morgan and Eve, 2012; Opitz and Johnson, 2016). The present research complements to this existing reflexive and multivocal approach in excavation and museum activities, by addressing ongoing "lab", or post-excavation research instead, and follows somewhat different and challenging routes to enthuse and involve the general public into an archaeological research project. What shall become clear is that some aspects of typical collecting and recording methods, and their inherent gestures and actions, are hard to digitally classify, let alone channel into existing metadata categories. This is due to the creative and dynamic nature of the archaeological discipline and its myriad (national) research traditions, as well as its focus on the reconstruction of past human behaviour, making it hard to realise attempts to capture and standardise all facets of past and present human practice (after Bowker and Star, 1999).

The affordances of digital devices and impact on collection and recording strategies of the Tracing the Potter's Wheel-project, have been analysed to assess what practitioners actually do while interacting with their tools. The analysis was carried out within the framework of the "Tradition in Transition" approach, an integrated praxeological and reflexive methodology (as formulated in Opgenhaffen, 2021). In doing so, it might be unravelled how these physical and intellectual processes of differentiation and classification in a given practice, with its methods and gestures, are translated into database structures and metadata categories. From here, it is possible to explore how the design of the database interface may constitute this translation of intellectual reasoning process in a similar fashion to the traditional written scholarly argument, and how user navigation could serve as a new form of scholarly inquiry (Daniel, 2014) beyond an "expanded readership" (Opitz, 2018, S71). Finally, an outreach model will be presented to address diverse audiences to use archaeological project archives and to stimulate public participation into archaeological research and knowledge production.

2. From data repositories to archives in action

Digital-born archaeological archives with 3D content either focus on the publication of excavation data and reports, such as the ADS,[2] tDAR,[3] Open Context,[4] or are aimed at 3D reconstructed architecture linked to a database (Clarke, 2016; Dell'Unto et al., 2016; Huurdeman and Piccoli, 2021; Noordegraaf et al., 2016). Other archives are catered to the presentation and pedagogical value of 3D collections (Ekengren et al., 2021), or to a lesser degree on projects that focus on non-site specific research such as (3D) pottery databases (for example Anichini et al., 2020; Di Angelo et al., 2021; 'The Levantine Ceramics Project',[5]; Europeana[6]). Research into the impact of digital technology upon archives and how this transformed archiving practices in research environments, however, has received less attention. Current research often treats digital archives as static entities which may be searchable offer data as downloads at best, although this trend is increasingly challenged (by, for example, Cameron, 2021).

Yet, at their introduction, new technologies such as the printing press, lithography, photography, film, computers and the world wide web did and still do have an impact on archiving practice. In particular, digital media seems to have led to a "general storage mania" (Røssaak, 2010, p. 11) and "fetishisation of data" (Sørensen, 2017). Everything has to be recorded and stored, in order to safeguard transparency and permanency of the collection and reasoning process, or so it seems to be thought. However, amassing research data without proper access can easily become a dead archive, "billions of files lie like sediment in the cloud, in hard drives" (Cameron, 2021, p. 4).. And unused archives are not the typical collections in which institutions are eager to invest money to maintain and sustain them.

Fortunately, there is a growing attention for data management and curation in the academic world (Dallas, 2015; Faniel et al., 2018; Richards et al., 2021). There is also an increasing body of literature, including dedicated special issues, on archiving practice in archaeology and heritage (Bauer-Clapp and Kirakosian, 2017; Benden and Taft, 2019; Faniel et al., 2018; Kansa and Kansa, 2018; King and Samford, 2019),[7] and research into digital collections and archives concerning the "accessibility" of digital data, "finding aids for collections" (for example, King and Samford 2019), or on "data availability" that might be reused by researchers (Faniel et al., 2018; Introsp. Digit. Archaeol.; 2019, and for an apt analysis of actual reuse, Geser, 2021; McManamon et al., 2017; Sobotkova, 2018; Wilkinson et al., 2016). However, these papers typically focus on the accessibility of digital repositories and the ease of finding and (re)using data once within the archive. How potential users are reached and informed about the existence of these important digital archaeological collections and overarching platforms remains an issue largely untouched. An analysis of who these users are exactly is also rarely studied (although there are some attempts, for example, McManamon et al., 2017). The current debate revolves around the uses of *data*, instead of the *users* of data, and overlooks the *human* performative process of archiving and the creation of data as an essential interceding principle between these two elements. For instance, Angela Labrador regards archaeological databases to have "social lives" (Labrador, 2012, p. 238), as they reflect socially informed creative practice but also exist beyond its making. Also, the online archive can be perceived as a "contact zone" of knowledge creation (Boast and Biehl, 2011, p. 119), exchange and transfer, and as a place of learning, by all kinds of participants, from laymen to apprentices and specialist scholars. In short, the digital-born archaeological research archive is a socially constituted, living and infinite environment about past and present human activity.

Moving forward with the idea of a living and, as such, progressing archive, we bump into the paradoxical notion that archives can both arrest time, as it preserves data for an indefinite time, as well as activate data through its subsequent use and ensuing knowledge generation. Akin to Eivind Røssaak's (2010) idea of an "archive in motion", this paper introduces the concept of the "archive in action", which is regarded as an ongoing process where data and archiving practices are used, reproduced, and re-used (or "recycled", as Jeremy Huggett (2018) prefers) through a series of actions by members of a community by employing digital, web-based technology. This social engagement performs as well as facilitates a tradition of knowledge producing practices of archaeologists (Paalman et al., 2021, pp. 3–4). A practice that is in its essence profoundly human yet overshadowed by the "datafication" of archaeology (Huggett, 2020, p. 2; Kansa, 2016, p. 467).

Archives reconstruct multiple intricate narratives about past and

[2] https://archaeologydataservice.ac.uk/.
[3] https://www.tdar.org/
[4] https://opencontext.org/
[5] The Levantine Ceramics Project. URL https://www.levantineceramics.org/ (accessed 6.17.21)
[6] https://classic.europeana.eu/portal/en.
[7] For example, see several Special Issues dedicated to archives in Advances in Archaeological Practice.

present human behaviour. The example presented here is about ancient technology, specifically the introduction and uptake of the potter's wheel into an existing potting tradition, as well as the application of digital 3D technology in a current archaeological visualisation tradition to analyse those ancient ceramics. Modern digital technology enables archaeologists to record and analyse these past practices more efficiently and in more detail. Additionally, the technology enables the archaeologist not only to disseminate conclusions to specialist and lay audiences, but also provides the potential to include non-specialists into the reconstruction of the past. Finally, digital research archives can act as powerful pedagogical tools in training students to become members of the community of archaeologists practicing a certain specialism.

Notwithstanding the difficulties of recording intangible human processes, the layered design and multiscalar use of TPW's Knowledge Hub reflects the complex workings of current and ancient practices nonetheless. This is represented by the availability of all kinds of data and the possibility to navigate and zoom in and out, for example, between the particular detail of a macrotrace to the mundane of a recording procedure, or from a production strategy to 3D metadata standards. This oscillation elevates the research project archive to a site of situated learning and exchange of knowledge and experience, and serves as a boundary object between several communities of practice (Bowker and Star, 1999). Used in this way, digital archives have the potential to draw together multiple communities of practice, of visualisers, digital archaeologists, pottery specialists, experimental archaeologists, professional potters, amateur potters, and many more. The traditionally separated practices, conventions and procedures of digital, visualisation, experimental and science-based communities of archaeologists are shared in this research archive, and subsequently used and learned by specialists, novices and lay persons who could then become a member of any of these communities and contribute to them with their own data and experience.

Despite the good democratic intentions of disclosing archives to the public, how do archaeologists know what non-experts expect to find or want to know? How can the TPW team member define their position in society to determine what data and knowledge should be recorded and shared, and with whom? To gain understanding of how specialists, apprentices and lay audiences receive, use, learn and contribute to the project archive, a critical yet preliminary analysis has been carried out in order to assess how this active and dynamic learning environment is experienced and perceived by its users. Lastly, the survey and analysis should determine if digital technology still affords, or perhaps even amplifies, a kind of materially dislocated yet very situated learning by its participants.

3. Archiving practice: an introspective analysis from an archaeologist's perspective

3.1. A framework to analyse archaeological archiving practice

A transparent archiving practice is the foundation for an accessible, inclusive and sustainable archive. In this paper, a deeper understanding of the processes of how creators and users find, receive and use the archive, is achieved by paying methodological attention towards the architecture that constitutes it. This architecture is shaped by the archaeologist's practice and choices in selecting, collecting and documenting artefacts. These activities do not happen in isolation, but by interacting with other agents – people, archaeological data and tools – and in space and time. As such, the architecture of the archive can be seen as a metaphor; similar to a real edifice, the archive's architecture is adapted, renovated and rebuilt over time to meet current aesthetic fashion, technological innovations and constructional requirements, and information standards, whereas the overall appearance may remain virtually the same.

By bringing the metaphor of architecture in practice, it can be assessed to what extent archaeological archiving trajectories have changed by the uptake and deployment of new recording and communication technology and changing societal standards. Did the operational sequences of recording practice remained unaltered, and only changed superficially, obfuscated by a digital smoke?

3.1.1. Methodology

The methodology applied to analyse the archival practice of the TPW project, is the conceptual framework Tradition in Transition, which has been formulated by the author elsewhere (Opgenhaffen, 2021). Tradition in Transition is an integrated, bottom-up approach that combines praxeological theory derived from sociology, such as the *chaîne opératoire* approach, with reflexivity. The *chaîne opératoire* allows to compare the technology (of material culture) to explain social processes. The layered approach considers a technical process as a meaningful sequence of performances and actions on matter in order to create a thing - whether this is digital or physical -, a process that is entrenched and occurring within a given social context. These performances and actions are associated with knowledge and technical know-how (Gosselain, 2019; Lemonnier, 1993; Leroi-Gourhan, 1993). In a similar fashion, in the context of digital archiving, the approach can be expanded with the conceptualisation of archiving practice of Fiona Cameron, who states that the collection of data is "a series of actions directed to framing the past and making judgments about what should be carried forward to the future" (Cameron, 2021, p. 4).

By treating the archive as an "information artefact", which consists of tools, systems, interfaces and devices to store, track and retrieve information (Star et al., 2003, p. 244), the framework also draws from STS methods too. The combination of these methods enables to apply a kind of reversed social engineering or "infrastructural inversion" (Bowker and Star, 1999, p. 34), a reflexive method to bring hidden practices behind digital infrastructures to the surface.

Exploring a project-based archiving practice and subsequent user experience of the archive, can be expanded by an autoethnographic (as introduced to archaeology by (Edgeworth, 2014, 2006) and introspective approach (as proposed by Huggett, 2015) which draw from feminist theory and affective, critical archiving (Brilmyer, 2018; Caswell and Cifor, 2016; Douglas and Mills, 2018; Evans et al., 2017; Srinivasan, 2017).

Firstly, an autoethnographic approach helps to create an awareness of the relational roles of researchers in knowledge producing practice, and how this affects data collection, curation and interpretation (Douglas and Mills, 2018, p. 263). The critical perspective enables researchers to convey personal knowledge, demonstrating the inner mechanisms and successful application of the proposed method. This process is recorded in the TPW project as paradata - here understood as the intellectual and personal information related to the documentation process of our interaction with artefact.

As history is indeterminate and changes over time, so is the narrative of the past continuously rephrased as well, as new voices enter the debate and old ones disappear. So secondly, the autoethnographic approach allows to analyse how other stakeholders participate in ongoing archaeological research and interact with the archive, hence producing a different kind of knowledge. This is reflected in the archive: traditional (archaeological) archives were hardly accessible, and the interpretation of the data in the archive was reserved for the institutional elite (Putnam, 2016). Digitisation processes enabled more groups to enter the archive and to participate in the formulation of the

archaeological narrative. 3D content even broadens the historical debate as they invite participants to engage with the 3D representations of cultural artefacts, and to interrogate the data for themselves, whereas the original material remains untouchable behind glass or in inaccessible storage rooms controlled by governments or (academic) institutions.

Transparency of data, design and practice, and ease of use of the archive are the result of an ongoing negotiation by these groups (Star et al., 2003).[8]

Working from the Tradition in Transition framework to investigate archaeological archiving traditions, the risk is averted that archives and archival practices become inaccessible black boxes of data and practice. The description of the creation of an archive in this paper and its subsequent uses in this paper will provide an example and could serve as a reflexive and praxeological approach of how scholars can perform and disseminate research transparently. In this way, the proposed approach and recording strategy responds to Jeremy Huggett's call for an introspective approach to archaeological practices (Huggett, 2015).

TPW had set itself a challenge to make invisible work visible because archives hold, besides object data, "a memory of work that has been done" (Bowker and Star, 1999, p. 253), an insight derived from early digital classification practice that resonates in recent information work today: "born-digital heritage and its collection therefore are about what we have done; what we value; how we thought about something; and what we experienced in the past that we see now as significant" (Cameron, 2021, p. 4), which represent the practices of that work as well. Whether Bronze Age potsherds are the object of study to identify technical acts left by a potter in a certain place at a certain point in time, or the creation of a digital archive of these studied potsherds by an archaeologist using digital tools to enhance the identification of traces left by those technical acts, the underlying mechanisms of making a thing remain the same. The Tradition in Transition framework conceptualises archiving archaeologists as making *choices*, a choice to adopt new digital technology and learn how to use it in order to enhance analytical practice, to retrieve more archaeological data and, ultimately, create new knowledge about past behaviour. The implementation of this framework into archaeological archiving practice, enables to map this practice which allows to identify, describe and assess the impact and efficiency of digital technology on practice (after Opgenhaffen, 2021, p. 1688).[9] Furthermore, the open-access publication of this mapped practice provides transparency of practice in all its facets, from tools to settings and social relations. Therefore, the TPW data, architecture and procedures, including decision-making processes, have been documented and mobilised in order to be learned and reproduced. How TPW has done that will be described in the next section.

3.2. *Reflexive praxis: the generation of data and the making of an archive*

In this section, the digital camera and 3D scanner are used to analyse the impact of digital devices on current recording practice and how these practices are reflected in the project's digital archive, in order to determine if TPW has adapted familiar practice to new digital tools. This disruption of research tradition may actually result in new types of data obtained by the new devices, which may ultimately lead to a different kind of knowledge.

[8] The author is aware of the current transparency debate in archive studies, especially in critical and radical archiving. In case of marginalised groups, full transparency can be unethical and undesired due to sensitive data (for example, Caswell and Cifor, 2016). Also access to stable internet prevents large groups from using online archives, risking inclusive archive to become exclusive instead. The GreenIT lobby warns furthermore that digitising and subsequent online storing and sharing has a devastating impact on the environment.

[9] The Tradition in Transition schema presented in Opgenhaffen 2021, provides guidance in the mapping of practice.

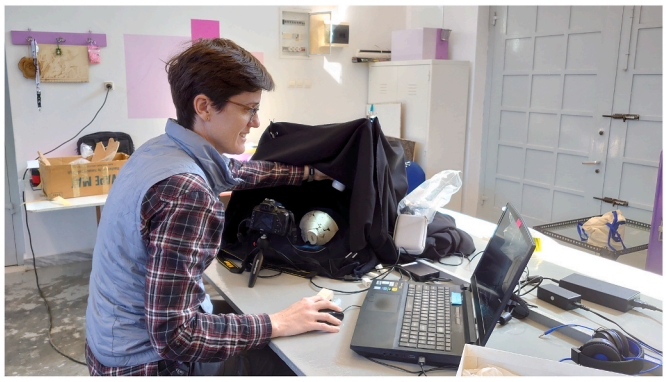

Fig. 1. The recording practice using digital photography by experimental archaeologist Caroline Jeffra (photo: author).

Fig. 2. The recording and analytical practice using a digital Dino-Lite by analytical archaeologist Jill Hilditch (photo: author).

3.2.1. *Selection and documentation procedure in the field*

TPW's aim is to find evidence of wheel-throwing, possibly alongside other wheel-forming techniques, which may inform about technological transmission between communities in the Late Bronze Age Aegean. Therefore, the team starts with selecting vessels according to size and shape. Then, a quick visual and tactile scan is made by the experienced experimental archaeologist to assess if the vessel is a viable candidate for in-depth analysis. Further analysis is carried out with the help of manually directed light, by touching the surface (moving the fingertips gently over the surface to tangibly retrieve information about how the pot was built) and sometimes with a small handheld digital microscope connected to a laptop to enhance visibility (a Dino-Lite). The traces are then documented with a DSLR camera tethered to a laptop via open-source camera controlling software digiCamControl, in combination with targeted light in a controlled light environment (a completely darkened portable photobooth) (Fig. 1). Additionally, but not always, pictures are taken with the Dino-Lite as well, which is controlled by Dino-lite's proprietary software for image examination and capture. All the optically discerned traces are described in a paper notebook and back in the office entered in the database, along with the photographs.

Macroscopic fabric analysis of the break and surface is then performed to determine a rough provenance of the vessel. This is done by the experienced eyes of the science-based archaeologist and frequently also with the Dino-Lite, which allows the taking of digital pictures to support the ocular observations (Fig. 2). The diagnostic features indicating the source of the clay are project-dependent, are described on a piece of paper, in a Word document, or in an excel sheet, and to be eventually transcribed into a database. These features, or classifications of entities, are described as well, and more advanced microscopes can be connected to a computer to enhance visibility and to obtain digital

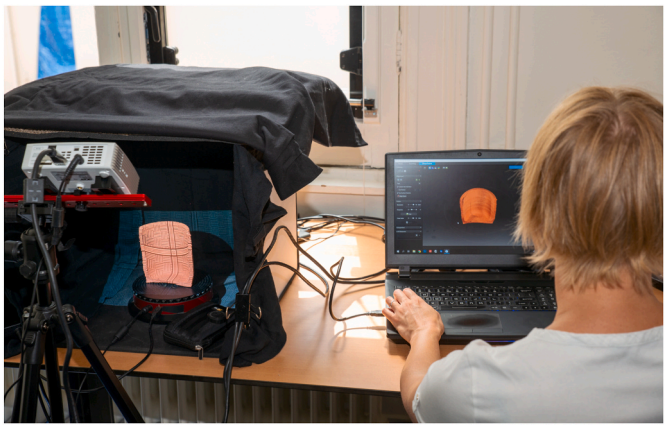

Fig. 3. The recording practice with a digital 3D scanner by digital archaeologist Loes Opgenhaffen (photo: author).

photographs.

These photographs can be digitally manipulated (or "enhanced") to increase visibility of inclusions and technological traits to support the interpretation based on observations.

This type of analysis requires an intensive and intimate interaction with the material and the analytical tool, involving delicate gestures to control the light, scale and sharpness. Occasionally, a sample of the material is selected for thin-section analysis in order to perform additional in-depth analysis with a microscope in the lab. However, this is often done once the entire assemblage has been studied to allow for representative samples for further analysis. Thin-section analysis can increase the resolution of the information about the provenance of the raw materials and provide more data about the composition of the clay paste. Such data provide can insights into the technological behaviours employed during clay paste processing (thereby strengthening the identification of a community of practice through the performance of specific production sequences).

Finally, only part of the investigated selection is digitally scanned in 3D by the digital archaeologist. High resolution 3D scanning of archaeological artefacts with usually a complex morphology is a slow process. Unlike digital optical devices, whether controlled from a laptop or not, the nature of the technology of the 3D scanner does impact the selection of material. Structure-from-Light (SLS) is the technology deployed in the recording practice. As the name already suggests, it involves the projection of light patterns onto the surface of the target vessel. A camera then records the distortions of the patterns where the light hits the surface. It also records the colour information of the vessel (the texture) as a photograph.

To determine the exact location in space, the software needs to calibrate the machine, which is stationary. Patterns printed on boards (calibration boards) are to be positioned on the location where the artefacts will be scanned. This location needs to be completely black, because black absorbs light, which reduces background noise. The calibration boards are of different sizes that correspond to the size of the artefacts. The machine also calibrates on the colour hue of the vessels. These parameters affect the process of selecting of material. The experimental and scientific archaeologist have to make a choice of which objects from the analysed, and in 2D documented, selection are important or suitable to be scanned in 3D, as only about 40% of the total of selected vessels can be scanned. Subsequently, the sub-selection has to be organised according to size and colour hue, which is in analogue recording practice usually less of an issue. The selection and documentation practice are therefore extended and adapted by the employment of new technology.

The 3D scanning process itself creates vast metadata, which is documented as well. For example, the calibration files are saved so that calibration information of specific scanning batches can be traced back. Also, circumstances are noted, such as light conditions, the stability of the floor and building and visitors. These factors all affect the scanning conditions: light interferes and disrupts the pattern projection, even minimally-unstable floors cause vibrations which are recorded by the machine, creating "ghost artefacts" (digitally generated traces that do not exist in reality) in the reconstructed digital geometry. Visitors passing by cause vibrations as well, or can accidently move the scanner or object.

During scanning, all of the operator's focus goes to the screen and the machine (Fig. 3). The artefact's position is sometimes adjusted for visibility by the camera, to achieve full coverage of the surface. As a result, this new technique is a disembodied addition to the archaeological practice of the visual inspection, as the material interaction is completely in the service of the machine. The traditional visual inspection, however, can be performed digitally on the digital 3D model with interactive 3D tools, but disconnected from the tangible original artefact. As such, the practice becomes expanded and dislocated, yet it does not comprise a completely new way of visual inspection but mimics digitally an analogue practice.[10]

3.2.2. *Post-processing practice in the lab*

So far, the wider public does not have access to the selected data yet. However, from the post-processing phase onwards, the outside world impacts the way we save and present the data obtained in the field.

Back in the office, the collected data, which consists of photographs, paper notebooks and 3D scans, has to be processed and integrated to form one coherent dataset. All targeted light photographs are entered in Adobe Lightroom, through which all metadata (such as camera and lens types, aperture, photographer, date and time, etc.), observed macro-traces, and basic physical characteristics of the object pictured is written to the photo metadata files through a tagging system. Subsequently, the photo-by-photo metadata is then exported from Adobe Lightroom using the plugin ListView to the web-based database. This is a manual and laborious task that involves a lot of screen-gazing and clicking, but the actual interaction with the original artefact, and the actions of ancient potters that they represent and which are tagged, are never far away.

Additionally, in order to understand the traces left in the ceramics by past potters, the experimental archaeologist produces pottery in similar shapes and forming techniques (wheel-throwing and wheel-coiling). In this way she can identify which trace was created by which action(s). The production of these modern examples of ancient shapes is recorded on digital video from one to two angles, so that all actions and gestures of the potter can be captured. This video material is then edited in Adobe Premiere Pro and uploaded to the database and YouTube, and assigned to the products, the pots, and the traces, both modern and ancient. All the modern vessels are studied in a similar fashion as the archaeological artefacts in the field – photographed, described and 3D scanned – and documented and entered into the database.

The 3D scans made in the field are post-processed back in the office, in order to leave more time in the field for the actual scanning of artefacts. The post-processing consists of hours of semi-automatic and manual "alignment" of the separate scans. Furthermore, the scans require to be "cleaned"; unclear and irrelevant parts ('noise') are removed manually from the scans. This involves a concentrated gaze at the computer screen while intensively hovering and heavily clicking with the mouse. This cleaning process consists of a chain of almost unconscious choices and decisions on what to remove and which parts are deemed relevant. When the computer is unable to automatically align the scans itself, the operating archaeologist has to identify visually matching features. All these choices, number of scans, "fusion" (creating one geometry from the separate scans) and export settings, are recorded

[10] The complete technical workflow can be found here: https://tracingthewheel.eu/article/workflow-series-sls-with-david (last accessed 3 February 2022)

and entered in the database, in order to preserve transparency and reproducibility of the practice. Although most attention goes to the digital geometry and visual integrity of the scanned result, observations of the actual represented artefact are sometimes made and communicated to the other team members.[11]

Lastly, the aligned 3D models are exported to different file formats and simplified (decimation of the number of vertices while preserving the overall topology of the model) in Meshlab to create smaller sizes. All changes made to the geometric properties of the 3D model, such as decrease in vertices and the removal of duplicated vertices, and the settings and parameters of this process, are recorded in the metadata fields of the database. Different formats and sizes are necessary to preserve accessibility, interoperability and usability of the models by fellow researchers for further analysis and interested parties. The repetitive actions and physical gestures involved in this final processing stage of the documentation practice suggest a misleading disembodiment between the original and digital 3D artefact – as there is no no seemingly material interaction with the either of the artefacts. In the final archiving stage, the 3D models and their meta- and paradata are entered into the database and embedded with the aforementioned other media and related data.

The 3D models are uploaded to a web-platform and enriched with information by tagging the macrotraces, which is visually indicating the traces in the surface of the model with hotspots and text. This set of actions means that the operating archaeologist requires, besides having technical skills, knowledge of ceramic forming technology. The operating archaeologist should able to recognise forming traces, also during the 3D scanning process, in order to assess if the relevant parts of the vessel are recorded sufficiently. This tagging stage involves real interaction with the digital artefact, and includes visual inspection in a traditional fashion: rotating the object, zooming/panning, directing light over the surface (if the functionality is available) and identifying the trace. Finally, the 3D models of the open-access online platform are embedded in the TPW Knowledge Hub (that is, once all necessary permissions have been granted by the relevant cultural institutions). In this Knowledge Hub, the 3D models and other media and data are presented in a visually coherent way.[12]

3.2.3. *Transitioning practice: layered complexity*

By describing minutely the practice of collecting and recording, and while creating an archive, the increased complex layering of a particular archaeological tradition becomes visible.

Rather than replacing an older recording technique, the new tools instead add methods and actions to the existing operational sequence. Photography has been part of the systematic archaeological recording and documentation sequence for over a century, but the technological innovation of the digital element to photography enables to create an unprecedented vast archive of ancient forming technology, which can be published in its entirety, and publicly, due to the adoption of web-based data systems. The recording and, especially, processing procedures, however, require more intermediate steps than in the analogue era, as more data about the data needs to be recorded in order to safeguard intellectual and empirical transparency.

Digital 3D scanning is, however, an entirely new method to the practice of recording, archiving and ultimately data visualisation. The 3D scanner enforces a different kind of material interaction between device, operator and artefact, and its operation is distinct from

previous, analogue visualisation methods. It increases recording and documentation time in research into ancient technology and affects the selection procedure of artefacts. The event (or sequence) of post-processing is far more complex than the digitisation process of hand drawings in for example Adobe Illustrator and the act of 2D scanning before that. The multitude of actions necessary to create a 3D model and the subsequent additional actions to generate models that are also useable by other stakeholders, as well as the metadata to document the tools and operational actions involved, significantly exceed analogue practice. However, the possibility to now perform visual inspection and analysis with the same yet virtual tools (such as the torch and sections), from a desk anywhere in the world, instead of costly travel museums, excavation depots and paper archives with limited accessibility, and with associated information instantly available with the digital artefact, enhances analogue practice in an unprecedented way. Printing the artefacts in 3D can return a different aspect of physicality, as the tactile inspection of ceramics is irreplaceable and indispensable in learning trajectories.

3.3. *Reflection: an enhanced practice*

It may be concluded that a different collection practice is affecting the answers that are generated from the analysis of the increased amount of data. This analysis depends on the organisation and design of the digital research archive that allows the availability of the material. Complex data systems are required that go beyond passive storage of raw data, but serve as active knowledge generating tools supported by metadata derived from collection to data entry and interpretation. Such archives respond to democratic calls from societal developments, and enable full transparency of the entire chain of research, within of course the boundaries of European directives[13] on open data and the re-use of public sector information (which research data of universities is) and national and international privacy laws (AVG, GDPR). The reflexive, praxeological approach of data archiving enables the reproduction of workflows which ultimately enhances comparability between (increasingly vast) datasets. The resulting interpretation of these large amounts of data and their comparison could lead to new knowledge about, for example, past potting practices and present archaeological knowledge practices.

The tradition of creating archaeological project archives may not have changed in its essence, but the way these archives are organized and designed have changed the way data is curated, shared and published. The digital possibilities afford to publish all photographs and 3D models, whereas previously only a selection could be published due to the limitations of traditional paper media. Moreover, these media are dynamically enriched with associated data and metadata, supporting the reasoning process of the archaeologists who created it, while allowing other stakeholders to inspect, correct and create observations as well. Traditionally, at least in the particular case of ceramics analysis and more specifically research to pottery forming technology, this reasoning process remained a mystery and was not published with the scant printed visual evidence. With one major exception: the online journal ARKEOTEK. Although it did not facilitate 3D content, the principal objective of ARKEOTEK was to create a knowledge base centred on the "archaeology of techniques", similar to the TPW Knowledge Hub mission, but without the multivocal component. Here, experts shared their research through the "hybrid" publication of not only datasets and results, but also the reasoning processes built upon them by linking the arguments to the evidence (Gardin and Roux, 2004).

The greatest advantage afforded by digital technology resides, however, in the presentation of the data and the use of the archive by specialists and non-specialists alike. An active archive may serve as a

[11] The complete technical workflow can be found here: https://tracingthewheel.eu/article/tpw-workflow-series-post-processing-3d-scans (last accessed 3 February 2022)

[12] The complete technical workflow can be found here: https://tracingthewheel.eu/article/tpw-workflow-series-democratising-3d-data-recording-the-process-of-3d-scanning-and-processing (last accessed 3 February 2022)

[13] European directive 2019/1024 on open data and the re-use of public sector information (https://eur-lex.europa.eu/eli/dir/2019/1024/oj) (last accessed 21 February 2022)

knowledge hub, a place where different voices meet each other, forging new insights and interpretations about people in the past. The next section will explore the dynamics of such potential uses.

4. Reaching diverse groups of targeted users for a project archive

4.1. The TPW Knowledge Hub

4.1.1. Description of the TPW knowledge hub

The organisation of the TPW Knowledge Hub[14] reflects the integrated practice of the project just described, as well as data and information about wheel-forming techniques and traces. The Knowledge Hub revolves around two focal points: as a place of knowledge exchange and as a place of learning. Both are based on a shared practice, visualised and communicated in different ways. Knowledge exchange takes place in the domain of "Collections", where datasets of members of the community of practice of pottery forming specialists are shared. These datasets may consist of experimental objects or archaeological artefacts. In the section on "Learning", both specialists, apprentices and interested lay persons can find procedures and workflows for 3D recording and collecting, as well as Learning Pathways on, for example, how to deposit datasets or to learn about forming traces. Finally, the section "Research" brings together the knowledge about ancient wheel-forming technology that has been gathered and created.

4.1.1.1. Collections. From the outset of the Tracing the Potter's Wheel-project, it has been the aim to not only publish its own datasets, but also to design the web-based archive as a place to collect and host similar datasets on the topic deposited by peers. The sharing of datasets enhances comparative potential, and increases knowledge about the uptake and adaptation of new technology such as the wheel into existing production strategies.

The object page consists of a large media viewer accompanied by four or five tabs, representing Overview, Description, and Forming of the documented vessel – either archaeological or experimental. In the case of an experimentally produced object, the object page may be expanded with a tab showing a Production Video, and if available, with a 3D model tab (in both cases). The media viewer represents a high-resolution photograph. Below the viewer there is a slider of thumbnails showing the total amount of photographic documentation. In the tabs, metadata and paradata associated with the primary data are located together and are directly visible. This integrated demonstration of *data* represents the performative nature of data, and makes no hierarchical distinction between "raw" data, technical "metadata" or the intellectual "paradata", as all this data informs its creation and imbues the item with meaning.[15] This understanding of associated, contextual data, such as the remarks and description of the 3D scanning process and videos demonstrating the process of making each individual experimental pot, is the direct visualisation of the project's collaborative practice.

The Overview tab provides data about, for example, the shape and forming technique, but also clay type and the name of the potter (in case of an experimental dataset). The Description tab gives further data on the part of the pot represented ("object component") and the traces observed. It also provides technical details about the image and image capturing procedure (exposure, iso, lens used), as well as the opportunity to download the file. The Forming tab gives exclusively information about the object represented, such as observed traces and forming technique. The 3D model tab gives technical specifications about, for example, the scanner model, resolution, calibration details, information about export settings and the simplification procedure, the name of the maker of the 3D scan, and practical circumstances such as light conditions. Lastly, several downloads are made available of both raw scan files as several exported file types.

4.1.1.2. Research. The Collections section is first of all the place to publish datasets that form the backbone of research. The research that these datasets represent will be introduced in dedicated blogs. Other research outputs, often conventional forms of publication, can be found in the Research Outputs section. Ultimately, the collections are the place to exchange knowledge; commenting functionality on visual media can help specialists to find out more about the object, for example, to identify traces missed by colleagues or to correct traces or interpretations. This functionality, which is at the time of writing only available under the 3D models on Sketchfab,[16] can instigate constructive discussions on the subject, and can be identified as a new form of scholarly reasoning beyond traditional scientific exchange and knowledge transfer.

4.1.1.3. Learning. Actions such as commenting on objects, learning to recognise forming traces in ancient pottery, reproducing a collection practice, navigating through the database or obtaining practical skills in 3D scanning, all constitute archaeological knowledge producing practice. TPW is developing Learning Pathways (LPs) to introduce novices and specialists alike to the community of practice dedicated to studying pottery forming. LPs are powerful pedagogical tools that enables the raw data to be enriched with arguments and synthesis for a wide audience.[17] By following the FAIR principles,[18] LPs ensure reproducibility, comparability and sustainability of digital scholarship by acting as interlinked articles and data which together demonstrate the entire research trajectory from data selection and collection to analysis and interpretation.[19] They furthermore represent the paradata, or reasoning process and knowledge production behind the data, while simultaneously preserving transparency and the possibility to reproduce the practice including all gestures and inherent choices. LPs break data in the Knowledge Hub into different comprehensible bits tailored to students in technological research to ceramics or digital applications in archaeology. Other LPs may guide specialists through the Knowledge Hub, acting as user guide. Although most LPs are in the design stage, some examples can already be given to illustrate the complexity and rich potential that such a framework can offer: The Reference Collection and the TPW Workflow Series.

The reference collection

[14] https://tracingthewheel.eu/(last accessed 3 February 2022)

[15] For more information about the project's definitions of metadata and paradata, see (Opgenhaffen et al., in press). And for more information about the subjectivity, contextuality and inherent socio-cultural implications of data, see, for example,Huggett (2019),2020, section 2;Labrador (2012);Sørensen (2017); Srinivasan (2017).

[16] This limited functionality through Sketchfab will ultimately be replaced by 3DWorkSpace, an open science/interactive tool for 3D datasets, currently being developed by a collaboration of researchers from ACASA, the 4D Research Lab and CREATE of the University of Amsterdam and the Smithsonian Institute. This research project is funded by NWO Open Science Fund. 3DWorkSpace will adapt the open-source Voyager 3D digital curation tool suite by adding multi-authoring and commenting functionality, as well as expanding the annotation and narrative possibilities.

[17] For a more elaborate explanation about LPs, seeHilditch et al. (2021).

[18] The FAIR principles serve as guidelines, not standards, to facilitate the findability, accessibility and comparability of scientific data and workflows as well. For more information seeStrupler and Wilkinson (2017) andWilkinson et al. (2016).

[19] For more information about the database structure and workflows see www.tracingthewheel.eu and (Opgenhaffen et al., in press).

The experimental dataset of wheel-formed pottery created by TPW forms a reference collection that can be used to compare traces with archaeological examples, as well as to learn how to recognise traces in the pottery. This can be done either by browsing through the objects and by searching for particular types of traces in the search bar, or by going to the external 3D Reference Collection on Sketchfab (which is also integrated in the object viewer in the Knowledge Hub), where dedicated collections can be found. These collections are "The Reference Collection on Wheel-Coiling Traces",[20] "The Reference Collection on Wheel-Throwing Traces",[21] and "The TPW training set on wheel-coiling traces".[22] The specific forming traces in the 3D models in these collections are indicated by tags: visual clues in the model specifying the type of trace and an explanation about the trace. However, not all 3D models have those annotations, allowing students to learn to observe the traces themselves. Familiar tools, such as panning and rotating, but also directing light to highlight parts of the surface of the represented vessel, enable to partly simulate the physical practice of pottery analysis.[23]

The collection with the training set contains a selection of 3D models with clear traces and 3D models of traces, which have been extracted from pots and modified to enhance visibility (through exaggerating the traces by adding more depth or by enlarging them). These models can be downloaded and printed in 3D to be used in courses on recognising forming techniques, as tactile exploration is equally, if not the most important, part of identifying forming traces.

The TPW Workflow Series

The practice of archiving pottery in 3D as described in section 3.2, has been synthesised into practical workflows called the TPW Workflow Series. These descriptions are either written as a manual to guide 3D scanning and processing step by step,[24] as informative blogs about how to make data democratic by recording the creative process,[25] or tips and tricks about different scanner brands and DIY solutions.[26] Besides being valuable learning tools for students, these workflows can be (re)produced by other specialists in order to create quantitatively and qualitatively similar datasets, which will enhance the comparability of datasets and subsequent knowledge production.

4.1.2. Critical thoughts and issues about digital archives such as the TPW Knowledge Hub

An appealing and intuitively navigable website is crucial in user-centred design. Unlike other archaeological databases and websites, the developers of the TPW Knowledge Hub were first and foremost concerned with what the archaeologists of TPW would like to communicate and to whom exactly. Therefore, they first designed several mock-ups of layouts, after which the technology and system was adapted, instead of the other way round. This resulted in a smoothly running website that does not feel as a database due to its gallery format, but as a place where one can find information and interact with data. What furthermore distinguishes the Knowledge Hub from other databases is that 3D content is considered as complementary and not as a separate class.

According to ceramic specialists, the resemblance of the digital navigation and interactive tools to analogue practice, make the digital counterparts intuitive to use. The annotation functionality (native to several 3D viewers such as Sketchfab, 3DHOP and Voyager), however, adds an informative layer to the original artefact, as panning and rotating a 3D (or any) artefact does not convey much if not know what to look for. This annotation goes by "tagging" the traces in the 3D vessel. In these tags, information about the trace is provided and optionally enriched with hyperlinks for further reading. Perhaps the greatest advancement is the Knowledge Hub as a whole: specialists can access and analyse the material from their desk anywhere in the world. However, at the time of writing the Knowledge Hub is still under construction, and, for example, a comment functionality per object has yet to be implemented. Only then truly collaborative research can start.

Nevertheless, there are some issues that not only TPW but all archaeologists and heritage specialist should be aware of. An ongoing problem is true accessibility of data. TPW's principal aim is to have peers to share their datasets the Knowledge Hub and to exchange knowledge by participating in discussions on these shared objects. Despite TPW's democratic intentions, a complex mesh of transnational directives and national laws of governments, institutional incentives and even personal willingness of publishing data (for an excellent overview about current data stewardship in Greece, see Tsiafaki and Katsianis, 2021), financial and technological availability, deter full disclosure of archaeological data in (digital or analogue) open-access archives. This situation risks the exclusion of stakeholders other than privileged scholars to engage with the data and to participate in the production of new knowledge. This is not the place to fight the power concealed in and maintained by archives, but it is hoped that governments and institutes will take notice and start stirring along current societal waves, away from traditional ideas about proprietary rights.

Another form of exclusion is that institutions, projects and scholars, with limited budgets or residing and working in remote areas, cannot have full access to the Knowledge Hub. Poor or no broadband hinders using the Reference Collection and to interactively engage with for example the 3D models and YouTube videos. Related to exclusion is the directionality of "free search". Who decides what a user can find?

Related to this is the standardisation of data and its organisation, with as inherent consequence a degree of direction. Archaeologists determine what to select and document of an already fragmented past, and decide what is lost (Bauer-Clapp and Kirakosian, 2017). Fortunately, archaeological projects increasingly provide a transparent documentation and argumentation indicating why and what is not recorded, which at least prevent a permanent obsolescence. Nonetheless, a rigid search functionality affects, but also directs, data retrieval and use through the application of a particular search vocabulary. As the search labels are connected to the filters, and the filters to specific semantic data in the database, on which TPW built its narrative, the search is always directed. As a result, users are required to enter concept labels from a predefined set of specialist vocabulary that follows traditional standards, a problem already recognised a decade ago by Robin Boast and Peter Biehl (2011). Does this new technology based on older conventions obstruct the generation of new knowledge and chance discovery, or is this an acceptable consequence of a community-driven research-project database with clear goals?

Finally, how do we know what people are looking for and what do we want them to look for? An important insight is that non-specialist users are looking for *information* (Huvila, 2008, p. 17) and not the abstract data or individual records that digital archives tend to provide. By placing emphasis on the activities of producing experimental pottery, and analysing and recording ancient pottery, TPW's active archive has more explanatory power about past human potting practice, as well as what it is that archaeologists do. This is what the TPW project is keen to communicate and share, but how do we measure and assess potential

[20] https://sketchfab.com/tracingthewheel/collections/reference-collection-of-wheel-coiling-traces.
[21] https://sketchfab.com/tracingthewheel/collections/reference-collection-on-wheel-throwing-traces.
[22] https://sketchfab.com/tracingthewheel/collections/the-tpw-training-set-on-wheel-coiling-traces.
[23] See endnote 14. The embedded 3D viewer Sketchfab will be replaced by Voyager, which has more tools and functionality. Additionally, 3D WorksSpace will be applied to create LPs.
[24] https://tracingthewheel.eu/article/workflow-series-sls-with-david.
[25] https://tracingthewheel.eu/article/tpw-workflow-series-democratising-3d-data-recording-the-process-of-3d-scanning-and-processing.
[26] https://tracingthewheel.eu/article/obsolete-technology.

users (persons) experiencing the Knowledge Hub, and how the information is perceived? The next sections explore will explore these pressing aspects.

4.2. Research to the user experience of digital archaeological archives

The creator, user and archive-system meet through the interface. The user friendliness of the interface determines how smooth those interactions (operations and actions) run between data, media, its contributors and participants and different environments or visualisation levels (2D, 3D) (Lewis, 2012, p. 1267). Therefore, the development of an archive with optimal and inclusive usability is pivotal. These aspects afford how not only the use of the system is learned, but also facilitates how the knowledge is transferred and learned and new knowledge generated. Understanding the mechanisms of the interface from a social, use/user perspective or "the role of humans in complex systems" (Salvendy, 2012, p. xvi) enables to assess to what extent of the participatory goals of the archaeological archive are met and discloses co-creative processes of situated learning and knowledge production.

Little research into 3D user interfaces in heritage has been carried out so far (for an overview on 3D-related projects for heritage and a 3D user interface, see Huurdeman and Piccoli, 2021), and often user needs and usability are not the core objective.

Fortunately, this focus on data use, user interfaces and functionality of digital archives is shifting towards users as humans and true participation in archives. For example, uses and experiences of students using 3D collections to learn about artefacts have been preliminary investigated (Ekengren et al., 2021). Others have explored the aura and authenticity of 3D models by deploying user evaluations (Minete Cardozo and Papadopoulos, 2021). Lisa Börjesson recently mapped which information systems are currently in use to share archaeological information, in order to assess how archaeological knowledge is organised (Börjesson, 2021). Analysis of the uses of tDAR revealed that contributors "use content to preserve, make available" their content, and that it has been used for research into family and local histories (McManamon et al., 2017, pp. 242–245). An excellent survey on "community needs" among archaeologists and heritage specialists carried out by researchers from ARIADNEplus did not extend to (re)uses of publicly accessible repositories beyond the academic community (Geser, 2021).

These are exemplary attempts, demonstrating a nascent attention towards understanding the users (Huvila, 2008) and the "expectations, experiences and perceptions of the implications" of the public engaging with digital archives in archaeology (Andresen et al., 2020, p. 185). However, the actual processing of comments of lay-persons and "engaging users as contributor is still very rare" (Andresen et al., 2020, p. 204; Jansson, 2017, p. 516). This has parallels to a similar observation made in museology, where "these voices … rarely are they recorded in an enduring way in the museum's catalogue" (Boast and Biehl, 2011, p. 122). As a result, no set of standards or guidelines exist as of yet that facilitate the assessment of the user experience and user needs of online archaeological or heritage archives (Champion, 2019; Huurdeman and Piccoli, 2021), with a focus on the *learning* experience and subsequent knowledge creation.

It appears that persons have become quantifiable users (McNeil, 2020). But experience, learning and affect cannot be tracked with visitor or download numbers, as they do not really inform what people are doing – engage and interact with the data and internalise the information. So, the lamentable outcome is that the user does not really take a central place in the creation and assessment of archaeological archives. How to achieve a more central role for our targeted users? In the following section the results of a survey to the experience of users will be presented.

4.3. Who will experience the TPW Knowledge Hub? Introducing user personas to archaeology

The FAIR principles are a good starting point to disseminate research data, but they are not about human interaction. The principles are designed from a machine-actionability perspective (Wilkinson et al., 2016), based on the idea that people increasingly rely on computational applications to find and manage data. Although TPW adopted these principles successfully into the digital infrastructure of the Knowledge Hub to organise and manage all project data and associated knowledge, we do need to know *who* and *how* we envision actual humans to find and use the data, and how TPW would like to receive and create new knowledge through the interaction with peers and public.

Over the last decade or so, at least outside academia, user experience (UX) design has taken a central role in what people do, desire, exchange and want to achieve (Sherratt, 2021). User experience takes a broader perspective and considers the entire chain of interaction of the person with the machine or product, including affect and perception, in order to improve usability and the inherent transfer of knowledge. In academia, however, there is no (nor should there be) marketing point of view of "a product", but it has, for good reason, become an ethical obligation to disseminate academic results and knowledge to the public. Giving instructions on how to interact with the media and data in the Knowledge Hub are key in good UX design. But how do we know how these instructions are received and if they work? And will the instructions work for all kinds of users, is the interface design responding in an intuitive manner to different audiences, and is the design appealing in the same effective way? Designers often get the question to design something useful for "everyone", which risks overcomplexity, "over-choice" and ultimately design for "no-one" (Miaskiewicz and Kozar, 2011, p. 428). For that reason, adopting and implementing a Persona Model with specific descriptions of different target users, could be beneficial to scholars.

TPW has adopted the design thinking approach, which is a human-centred way to explore, predict and design online interactive behaviour, in alignment with the project goals (Opgenhaffen et al., in press). UX is rooted in this approach and serves as a method to develop the human-centred system of the Knowledge Hub (Ritter and Winterbottom, 2017). User personas help in ascertaining the interactive behaviour of the system (Zellhöfer, 2014). User personas are not actual persons, but rather are *imagined* composite biographies[27] or "hypothetical archetypes" (Cooper, 1999; in Nielsen et al., 2021, p. 330), based on research and experience to describe characteristics, needs and goals of actual people. They allow to think how users may want to interact with the data in the Knowledge Hub. Ideally, this could have helped the TPW team and the developers of Kbell&Postman to locate and understand learning difficulties already in the design stage (Pruitt and Adlin, 2006, p. 8). However, TPW has adopted this approach in a later stadium to improve the beta version and public outreach ends. Subsequently, adding visual cues to guide the users through the Hub, improve the user interface (UI) with optimal intuitive functionality and navigation (Ritter and Winterbottom, 2017), while shaping the information architecture underlying it. Several aspects depend on determining a user persona, such as research aims and the targeted impact of the system.

Creating user personas are, in a way, a kind of "applied ethnography" (Norman and Donald, 2013, 222). It ideally starts by collecting data about existing persons by employing interviews, field studies, surveys, user testing, tracking and beta version feedback (Pruitt and Adlin, 2006, p. 8). This research-based approach is further strengthened if personal experience is included into the personas (Nielsen et al., 2021), whereas assumptions on targeted users, or assumption-based personas, usually do not add to the creation of a stable persona and leads to more work in

[27] After https://www.productplan.com/learn/user-persona-vs-buyer-persona/Last accessed 19 January 2022.

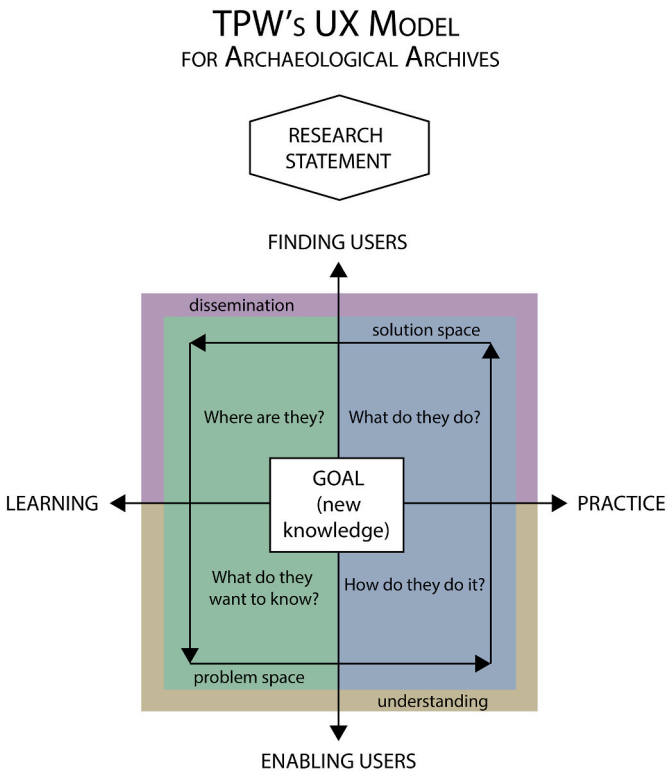

Fig. 4. The TPW's UX Model for Archaeological Archives (image: author).

adapting the UI (Marshall et al., 2015; Nielsen et al., 2021). Concepts such as age, gender and ethnicity, for example, are thought to cause assumptions. However, if the level of inclusivity of the Knowledge Hub is to be assessed, these aspects should be inquired. John Pruitt and Tamara Adlin advise to "embrace the challenge of communicating information about users through narrative and storytelling" (Pruitt and Adlin, 2006, p. 37).

Narrated personas can, besides being crucial in architecture and UI design, also assist in the development of user guides and LPs. The author took inspiration from the Persona Template as proposed by Marli Ritter and Cari Winterbottom (2017, p. 133), which has been further refined along the guidelines of the User Profile Model developed by Jessica Sherratt for UX Collective (Sherratt, 2021). It resulted in the "TPW's Persona Template" for UX design for archaeological projects.

The following steps describe the procedure of creating personas, as formulated for the Knowledge Hub, and for finding users and experience assessment of archaeological project archives.

Step 1. Start with a research statement: **What** are the research goals and aims of the website and/or system? **For** whom? **So that**? What should be achieved and should be the impact?

For TPW this would be firstly to facilitate specialists and students to use and reproduce TPW's archiving practice and workflows; and for laymen, students and non-specialised archaeologists to learn about ceramic forming technology/recognise traces; and to finally collect more data, so that more knowledge about the uptake and transmission of technology in the past is generated.

Step 2. Define the motivations of certain groups to find, search and use the data in the TPW Knowledge Hub:
- Demographics (education, age category, whereabouts).
- Who needs to be reached and why (occupation, profession)?
- Motivation of the user (interests and activities).

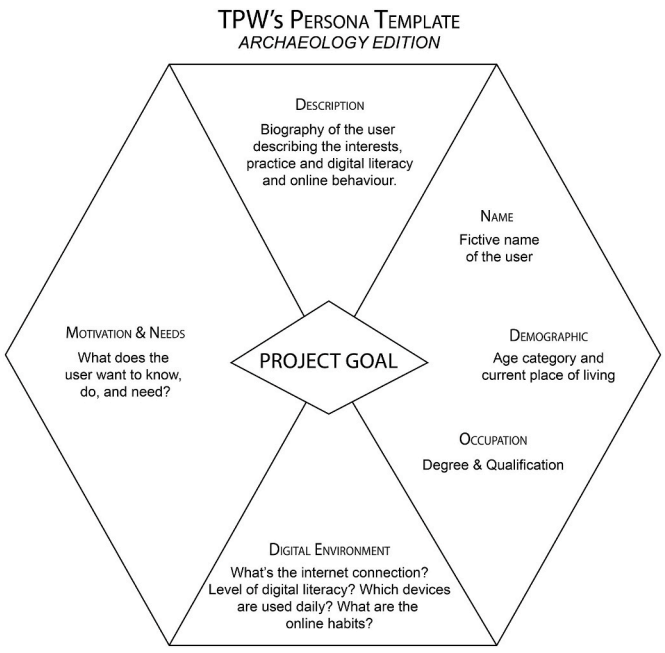

Fig. 5. TPW's Persona Template (image: author).

- Degree of digital literacy and available technology (i.e., devices, internet connection).
- What research practice is employed.
- What do people want to achieve/need/require?
- User scenarios (map the bottlenecks and potential frustrations).
- Empathic approach: understanding the experience.

Step 3. Things we want to assess:
- The **effectiveness**: which specified users can achieve what particular goals we want them to achieve? How easy do they get from A to B?
- How **efficiently** are the specified users going from A to B? Which resources are they using to get the desired results?
- Level of **satisfaction**: are the users happy or frustrated in their navigation through the system to obtain the results? How will this affect other potential users, if the system receives bad recommendations?

Step 4. Develop a survey through a questionnaire and/or interviews based on the information stated above to gather additional information if needed.

Step 5. This questionnaire can be adapted after beta-testing to inquire end-user experience and feed-back.

The author has designed a UX model (Fig. 4) that summarises and guides the UX design process of archaeological archives. It is a layered model representing the design process and assessment of the UX of an archaeological archive. The goal of the archaeological project and archive is always prominent, and the needs and desires of the targeted users and the aims of the archaeologists are clear. Once the main issues are identified, the problems and solutions layer enable to address the needs, behaviours and motivations of the users (problems), in order to improve the experience to access, navigate and use the platform. Once these are solved, the next layer offers understanding of the personas and the identification of the level of digital literacy and motivation to learn and/or contribute to knowledge production, the system can be disseminated to the targeted users based on the personas. The TPW's Persona Template (Fig. 5) guides the construction of these personas. This diamond-shaped template summarises the different aspects that make up an imagined protagonist of a targeted user group. The project or platform's goal takes, again, a central position and always stars in the description, implicitly or explicitly.

4.4. The questionnaire

The author has developed a questionnaire to identify who is visiting and using the Knowledge Hub, how they experience it and what they think of it. It is also designed to inquire what specialist users miss or expect to see in the Knowledge Hub, something we dubbed "User Desirability". The questionnaire was initially intended for end-users, but it informed the construction of user personas as well.

The questionnaire[28] is divided in five sections, which are all accompanied by a small introduction to explain why we want to know these things. The first section is set up to map the background of the users, in order to create a safe and inclusive digital environment. It includes questions about professional occupation, education and possible limited ability. The second section is dedicated to the learning experience of the Knowledge Hub, in order to inquire how people found the Knowledge Hub, navigated between the different sections within the website, perceived the information and used the data to learn about forming traces in pottery. The third part is oriented on the workflows that have been published on the website, to assess if they are clear and useful to people and if they would adopt and deploy them into their own practice. Actual user experience of particularly the Reference Collection and the objects in the database, is analysed in the fourth section. Lastly, in the fifth section, the general impressions about the design and functionality are queried, such as navigation between different assets as photos and 3D models. The survey was launched mid-November 2021, when the Knowledge Hub was still being refined, and is still running.

Complementary to the online questionnaire, personal informal interviews were taken among academic, specialist and lay persons. The preliminary responses of the questionnaire (n = 14) and interviews (n = 11) are too limited to generate decisive conclusions, but already adaptations to the system and design could be made, and user personas developed. The aim is to officially launch the Knowledge Hub with opening of the final exhibition of the Tracing the Potter's Wheel-project, in autumn 2022. Through this hybrid exhibition, about which more in the following section, we envisage to reach a greater audience beyond the specialist realm. The outcomes of this survey and testing of the proposed framework to determine targeted "audiences" and create true societal impact of archaeological project archives, will be published in a final paper.

The general idea is that UX metrics have to be quantifiable and for that (Tullis and Albert, 2013), the observations have to be translatable to numbers. The usability of a system, however, such as the navigation between the different types of media and search functionality, can only be truly assessed when it has been tested with real users interacting with it (Ritter and Winterbottom, 2017, p. 7). As experience is something inherently volatile and personal, open questions in the questionnaire are devised to identify those experiences.

The respondents of the questionnaire mostly occupy an academic position or are trained archaeologists active in the field (n = 12). Most are specialised in ceramics technology or material culture (75%), and 3 in digital archaeology (21.4%). Other (complementary) specialisations reported are building techniques and potting. An average proportion of the participants heard about the Knowledge Hub via colleagues (50%), family/friends (28.6%), social media (14.3%), online search on pottery technology (7.1%), and at a conference (7.1%). Half of the respondents were Dutch, others Belgian, German, French, Greek, Portuguese and Italian. Interestingly, the question about ethnicity did not result in an inclusive outcome: most reactions correspond the nationality.

Most of the respondents have read the posts about forming technology and had a look at the (3D) reference collection (71.4%) and learned something new (92.9%). A positive outcome is that, if applicable, 57.1% would implement the reference collection as a learning tool in their curriculum, and all respondents would recommend the Knowledge Hub to colleagues. In the third section about the workflows, however, 42.9% of the participants did not find the workflows, and when they did, 35.7% responded they were not relevant (as of yet), which is to be expected, considering the specialisations (ceramics and material culture) of the respondents (42.9% responded "not applicable"). However, the workflows are not only designed for digitally literate archaeologists, but also aimed to be adopted in research practice to ancient forming techniques.

In the fourth section about the user experience, only a small number of participants have used the reference collection to compare material (23.1%) - and they were 75% successful in identifying traces -, of which 66.7% would use the reference collection in the future.

In the fifth and last section about the design and functionality of the website and database as a whole, 71.4% of the participants think it has a clear usability and a positive design, and 21.4% is neutral about it. The search functionality was not received outstandingly: only 33.3% received the expected results, and 50% received only partly relevant and party strange results, and it was commented that it was experienced difficult to query the database. Exploring the database was considered either easy (50%) or a bit difficult, but manageable (35.7%), and it was experienced easy to navigate between different media (85.7%) and associated (meta and para) data (61.5%), and quite easy to explore the 3D content (64.3%). The participants spent moderately time exploring the Knowledge Hub: almost half of the respondents stayed 10–15 min, whereas 21.4% more than 15 min and 21.4% 5–10 min.

Finally, three respondents remarked in the final comment field that the overall impression, when first entering the website, the information is quite overwhelming, with "crowded pages".

When talking personally to different user groups - lay persons and colleagues - these remarks of the three respondents are confirmed: particularly a non-specialist, lay audience perceive the website as too massive and intimidating and hard to focus for a long time, and did not complete and submit the questionnaire because it was "too difficult". Other lay persons were very excited about the 3D models and videos, which are considered the most interesting and less abstract form of information. A very positive outcome of the informal interviews with archaeologists is that they recognise TPW's practice reflected in the organisation of the Knowledge Hub, especially in the presentation and organisation of the object/media viewer accompanied by associated data. A number of members of the community of practice of ceramic technology specialists have confirmed informally to contribute datasets to the Knowledge Hub. Some students (including student-assistants) in digital archaeology and material culture (n = 6, both academic and applied sciences) have successfully reproduced the 3D workflows (see Opgenhaffen, 2021, and the 3D models on Sketchfab).

What conclusions can be drawn from this? The information on the website, especially the landing page, has been adapted accordingly to divide the information in more concise and manageable chunks. There is a separate User Guide, a less dense menu header and submenus should now direct more clearly to the blogs and workflows. A major insight is the fact that only one lay person has filled out the questionnaire. From personal communication it became clear that although non-specialist users like to read about 3D printing, rotate 3D models and watch the potting videos, the information about traces is not reaching them. It can be determined that their online behaviour is different from the specialists who are already acquainted with the material and tend to stay longer on the website, than uninformed

persons who lose interest within 5 min. Together with the observations of museum audiences obtained during a small exhibition of the project called "Tracing the Conical Cup"[i] (Norman's "applied

[28] The questionnaire can be found here: https://docs.google.com/forms/d/e/1FAIpQLSc2GHiUrONJambAl7k8Wxz0gMcvuzRZycpGvU44HibGUGoapA/viewform Last accessed 26 January 2022.

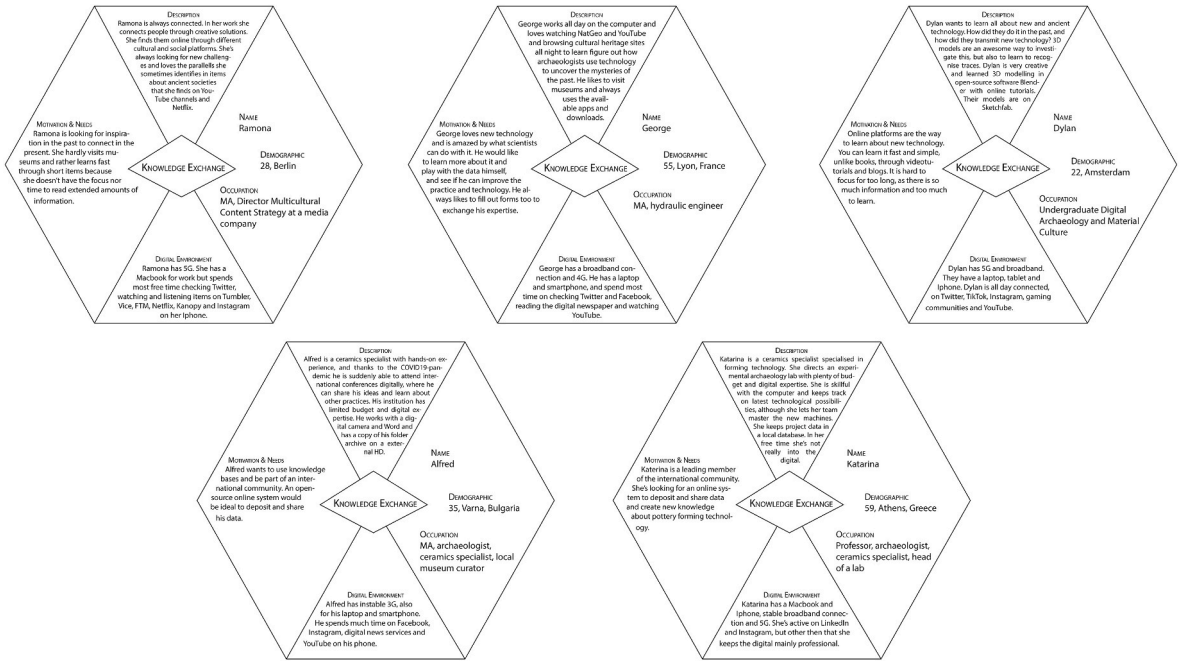

Fig. 6. a–e. Different types of user personas TPW aims to address. The personas range from younger and older lay persons with an interest for archaeology, to students and specialists with limited internet access and specialists with good internet access (images: author).

Fig. 7. The blacklight traces-station of the Conical Cup exhibition (photo: Caroline Jeffra).

anthropology", that is, to "go out there")[29], this proved to be valuable information for the creation of user personas (Fig. 6a–e). These can then inform how to guide and inform these user groups through the Knowledge Hub, and how to reach them through particular media channels associated with specific user personas, among which museum networks.

With these personas in mind – albeit informed by a very limited user base, and therefore presented here as a potential example -– TPW can promote the Knowledge Hub in more targeted ways. It became clear that not everyone can be reached, but specific groups can be designated to be addressed, while creating an open and an as transparent as possible environment. The community of established specialists has been informed through academic and specialist channels, but other archaeologists, potters (both artists and amateurs), museum visitors (or the greater mass of people who do not visit museums) and even students are a greater challenge to approach and to excite about ceramic forming technology and related research practice. How can a potential user find and use a Knowledge Hub about a subject they didn't know existed and were not looking for either? More data is required from the online survey and observation on the ground, however, this paper aimed to provide stepping stones to guide such an inquiry (Fig. 7).

5. Summary and future directions

The archaeological archiving tradition is in transition. The analytical tools and practices in the archaeological toolkit have remained largely the same, albeit replaced with digital surrogates. The intimate, tactile and visual practice of physical inspection of the archaeological material, has in particular cases been affected by the deployment in this practice

[29] https://tracingthewheel.eu/page/exhibition (last accessed 31 January 2022)

of digital recording devices, such as a 3D scanner. However, the publicly published 3D content enables a different kind of embodied practice with the original artefacts, which can now be visually interrogated by anyone anywhere in the world with similar yet virtual tools. The introspective analysis of TPW's archiving practice and critical description of the online archive, has demonstrated that the adoption and implementation of digital (3D) visualisation technology into archaeological collection and recording practice in particularly the specialisation of ceramics analysis, is transforming the archive from a passive storage facility towards an active and dynamic place of sharing and exchanging archaeological knowledge about pottery forming technology.

The issues and outcomes of this paper may be summarised as follows. The point of departure of the paper was the statement that a digital archaeological project archive is not a passive repository of data, but a dynamic and participatory environment of data and knowledge exchange and learning. Furthermore, the digital archive could be a transparent site of scientific reasoning. The premise for a transparent process is to place equal importance on sharing data and on sharing (project-based) archiving practice, which enables to create similar datasets that increases their comparability and reproducibility. In order to guide the mapping of this practice, the reflexive and praxis-oriented Tradition in Tradition framework has been applied. By scrutinising and analysing the sequence of actions, tool-use and inherent gestures of and interaction between the members of TPW (following the *chaîne opératoire* approach), the impact of the digital tools could be assessed. But not only that: the mapping of archiving practice and subsequent open-access publication in this journal and on the TPW Knowledge Hub, creates the potential to advance the *practice* to a standardised *procedure*, if adopted, adapted and further refined, and reproduced by other members of the community of practice of pottery specialists. An important insight that came with this framework is that it can be applied as infrastructural inversion: as reflexive method to bring hidden scientific practices behind digital infrastructures to the surface. This is what makes the archive not only a data repository, but an open space for exchange of experience and expertise between specialists (Boast and Biehl, 2011), as a dislocated yet situated *lieux the savoir* (Huvila et al., 2018) and place of encounters between human and non-human encounters (Cameron, 2007; Ireland and Bell, 2021). As such, the performative nature of the archive, as a dynamic social space where archiving continues as its multiple usages of data and procedures create and add more data and diverse knowledge, this recurrent motion of archiving practice beyond the trowel's edge and storage room, as a multivocal research process. The reflexive approach pushes further democratisation of digital archives as opposed to analogue archives by disclosing virtually archaeological material outside the inaccessible excavation and museum storages and showcases. This material can now be studied be other experts from all over the world, widening the debate on forming technology from linear presentation of a few slides of archaeological material on physical symposia, to an interactive discussion about any fragment from Argentina to Amsterdam; ultimately increasing knowledge about forming technology. Yet specialised archaeologists are not the only targeted audiences of TPW. From the outset, the collection and recording procedure was designed to be shared with apprentices and interested lay audiences as well, as a new kind of interactive learning aid. Especially the experimentally produced ceramics were aimed to form an online reference collection about ceramic forming traces and techniques. Usually, analogue reference collections are limited to a few specialised academic institutions, but online they become accessible to all. A few specialists have already indicated that they would adopt the online reference collection with 3D content into their curriculum, and the very preliminary responses from the online survey showed that non-specialised archaeologists plan to use it during fieldwork as well, as a comparative resource.

Lastly, to include other voices than archaeologists, and to create a user-friendly digital system accessible and useable to multiple designated communities, the user should take a central position, not simply the uses of data. The following notions and approaches were developed to meet expectations and reach people. An archaeological project should start with adopting a user oriented instead of a system-oriented survey to experience, because this will make a user a person again, and moves the focus on data uses to persons using data. Design thinking is such a user-oriented approach, and it should be implemented at an early stage of database development and UX design. To determine and improve the UX of the project archive, user personas are a valuable way to determine anticipated and targeted user groups.

Lastly, a solution has been developed to reach diverse audiences and to promote the digital archive: hybrid exhibitions of post-excavation and project-based, ongoing archaeological research are the way forward from conventional exhibitions, and stimulate the promotion of archaeological archives and innovative archaeological practice.

The infrastructure and technical know-how have arrived at advanced stages and been implemented at a few institutions. But digital recording is not an end goal on itself. It is merely a technique to advance the study of past human behaviour and society as well as present research into this. Last case in point is that opening up an archive to all does not necessarily mean that everybody needs or will use it, or is able to find it. It has been acknowledged in this paper that not every social group can be reached, but that the archive should be designed in a way that it is open and welcoming to everyone nonetheless. Transparency of practice is key here. By disseminating data and practice in an open and active infrastructure, other stakeholders are offered the possibility to use the material in the archive in order to understand what moved past people when practicing technologies and how present archaeologists engage with this. This movement keeps the archive in action.

Declaration of competing interest

The author states no conflict of interest.

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