Research Article

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Tradition in Transition: Technology and Change in Archaeological Visualisation Practice

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Abstract: Archaeologists are the mediators between fragmented, and often contested, pasts and the momentary present. To record, organise, interpret, and reconstruct complex narratives of the past and to communicate these to present-day peers and the public, they use a wide range of visualisation methods. As such, visualisation methods form an intrinsic part of the representation of practical and intellectual findings, being crucial to knowledge production in archaeology. The adoption and adaptation of digital visualisation technology changes the way archaeologists shape new knowledge. However, for a discipline that is particularly concerned with how technology had an effect on past societies, for example, the impact of the potter's wheel on local ceramic production strategies, archaeologists have a remarkably limited awareness of how current (digital) technology has an impact on their own visualisation practice and the subsequent knowledge production. This study presents the conceptual framework “tradition in transition,” which integrates technological and visualisation methodologies, and aims to provide a framework to analyse the underlying processes and mechanisms that shape and change the practice of creating visualisations.

Keywords: practice theory, reflexivity, *chaîne opératoire*, 3D visualisation, methodology

1 Introduction

Archaeology is predominantly a visual discipline about things (Olsen, 2010; Olsen, Shanks, Webmoor, & Witmore, 2012; Witmore, 2006) that heavily relies on the visualisation of these things. To record, organise, interpret, and reconstruct complex narratives of the past and to communicate them to present-day peers and the public, archaeologists use a wide range of visualisation techniques. Yet, for a discipline equipped with theoretical approaches and methods to assess how technology had an effect on past societies, for example, the impact of the potter's wheel on ceramic production in the Aegean Bronze Age, archaeologists have surprisingly little awareness of how current (digital) technology has an impact on their own visualisation practice and the subsequent knowledge production. Even today, after the “material turn” that has placed an ontological emphasis on the material, productive aspects of things and their interdependence with people and visualisations of things are nevertheless deprived of their human origin.

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Daunting, scientific-looking visualised statistics are produced as if no human was involved in processing the data and as if no potter made the pots which the digits represent.

Fortunately, the epistemic role of both visualisers and visualisations in archaeological meaning-making practice is increasingly recognised by the visualising community itself, originating in Stuart Piggott's study (Piggott, 1965, 1978). However, the practice of visualisation has become progressively more complex since the uptake and deployment of digital (3D [three-dimensional]) technology into existing visualisation strategies, and the resulting dynamics of this heuristic and creative process are not fully within the spectrum of the archaeologist's gaze yet. Perhaps, this is due to the invisibility of the craft and scientific research skills of the archaeological visualiser in the visual outputs, and that these skills are not mentioned or explicitly connected to the visualisation either (Maxwell, 2017; Perry, 2015). Although it is increasingly customary within the field of scientific virtual 3D reconstructions to make the creation and decision-making progress of the visualiser transparent and accessible, this is less so for other visual formats, for example, digital 3D scans of artefacts. This last category is generally regarded as a static mechanical, dehumanised production process, a digital copy of an analogue original artefact. Yet, a visualisation is much more than a technique or a "statement of reality" (Clark, 2010, p. 63), it is a creative, generative, and experiential research method that considers the multiple human and material/nonhuman digital agents in the process of translation of artefacts into visual formats. Technological choice takes a central role in this creative process as it represents some factors behind the adoption and adaptation of new technology into existing visualisation practice. Both visual products and archaeological artefacts are the "material correlates" of this process and are, moreover, interrelated with epistemological concerns that relate to knowledge production about the past (Hilditch, 2020; Svabo & Shanks, 2013). However, Isto Huvila and Jeremy Huggett have signaled an insufficient understanding of how archaeological remains are recorded and how new knowledge is generated from this data and have proposed to draw from practice theory to increase this understanding (Huvila & Huggett, 2018). This study assesses the extent to which archaeological visualisation practice has transformed or changed in response to an increasingly digital discipline using 3D technology.

But what exactly is "traditional" archaeological visualisation? The most common recording practice for archaeological artefacts today is still manual archaeological illustration and digitisation in Adobe Illustrator or other image processing software. The automation of conventional recording practices with innovative 3D technology and software started in the mid-2000s focusing primarily on automatically generating familiar two-dimensional (2D) technical illustrations of artefacts (Gilboa, Karasik, Sharon, & Smilansky, 2004; Kampel & Sablatnig, 2006; Karasik & Smilansky, 2008; Martínez Carrillo, Ruiz Rodríguez, & Rubio Paramio, 2010; Salvadori, 2003; Smith et al., 2014; Wilczek et al., 2018). This particular technique did not, however, become widely adopted by archaeologists or illustrators, whereas a decade earlier, a new method for digitalising drawings with Adobe Illustrator did find its way into wider visualisation practices. Ethnoarchaeologist Valentine Roux has stated that "tradition ensures knowledge production" (Roux & Courty, 2019, p. 6), yet such automation of existing visualisation traditions did not automatically lead to new knowledge, despite the production of more digital data. Is it the case that the technical reasons and social conditions responsible for the adoption or rejection of such innovations in existing visualisation strategies is contingent upon the generation of new knowledge?

Gareth Beale and Paul Reilly have recognised "emerging traditions" of a distinctly digital nature within the archaeological community (Beale & Reilly, 2017b). Traditions, however, are processes that undergo a long development that are then maintained and reproduced over time and, hence, can only be identified when techniques and methods are repeatedly used. What can be measured, fortunately, is the extent to which 3D tools and techniques are changing the way archaeological visualisers (archaeologists and external illustrators alike) produce artefact visualisations. When archaeological practice is considered as a "craft activity" or "creative practice," as Beale and Reilly (2017b) propose, with a focus on not only the interaction between archaeologists themselves but also with their tools and material context, then change or adaptation of technical traditions may indeed be identified. In fact, the study of performative acts, being "the physical [or digital] renderings of mental schemes learned through tradition" (Lemonnier, 1993, p. 3), may be the key to obtaining a greater understanding of what current archaeological "tradition" is and to what extent this visualisation tradition differs from earlier traditions – as opposed to the idea that traditions

can only be understood *a posteriori*. The following discussion investigates the technical knowledge involved in the creation of a visualisation of an artefact, specifically when a new (3D) technology is introduced and adopted into an existing practice, and explores the underlying processes and mechanisms that shape and change this practice. To this end, the concept of “tradition in transition” is presented, a methodological framework combining practice and social theory with a reflexive approach, which enables us to interrogate the incremental creative steps within technological processes that occur within a social environment.

The deliberate emphasis on artefact visualisation and not site documentation, architectural reconstruction, or the automation of pottery documentation in 3D is due to the experience of the author and her current research project. The Tracing the Potter’s Wheel (TPW) project at the University of Amsterdam¹ presents an innovative approach to investigate ancient technological trajectories and cultural encounters in the Bronze Age Aegean (2500–1200 BC) through the integration of material analysis, experimental archaeology, and digital archaeological approaches. The project focuses on the identification and assessment of the appearance of the potter’s wheel as a technological innovation and its adoption and adaptation (or rejection) into existing local potting strategies. The shared conceptual framework of the project is built on the *chaîne opératoire* approach, a praxis-oriented approach with roots in sociology (Hilditch, 2020; Jeffra, 2015a). During this project, questions were raised about the author’s own changing visualisation practice alongside a growing self-awareness of both the agency and the reciprocal role that tools and equipment play in the visualisation process. The TPW project is a useful case study to not only present analogies between past and present practices but also to explore the ways in which archaeologists can study these practices. The author’s research in TPW also aims to connect what archaeologists actually do, why they do it (knowledge about the past, meaning in the present), and how they use digital (3D) tools and techniques to visualise and produce that knowledge.

Sorin Hermon has already introduced the *chaîne opératoire* approach as a method to structure research using digital 3D visualisation for investigating archaeological artefacts and creating 3D reconstructions (Hermon, 2012; Hermon, Polig, Driessen, Jans, & Bretschneider, 2018). The “tradition in transition” framework takes Hermon’s study as a starting point and builds on this promising approach by expanding the practical to the social, as performative methods can serve as heuristic tools for the behavioural study of knowledge-producing archaeologists. The proposed framework is also an answer to recent calls for an introspective (digital) archaeology (see Huggett, 2015a; Perry & Taylor, 2018). It furthermore provides a methodological and tailored solution to the unsuccessful implementation of the London Charter and similar initiatives (for a recent critical assessment of the charters, see Opgenhaffen, Revello Lami, & Mickleburgh, 2021). The agency of the visualising archaeologist and material engagement with both tools and archaeological material take a central place in this versatile framework, rather than creating or highlighting a set of equivocal guidelines emphasising the use of digital tools. The framework also addresses the pressing need for transparency of data and workflows alike, through the reflexive recording of the decision-making process of the visualising archaeologist.

2 The Theory: Praxeological and Reflexive Approaches Combined

2.1 Becoming Digital

Before my current research, I was an independent and traditionally trained archaeological illustrator, increasingly turning my focus to digital (3D) applications to meet growing commercial and scientific demands for fast, accurate documentation, and 3D reconstructions. Although I was adopting and learning

¹ This 5-year research project is funded by the Dutch Research Council (NWO), directed by Dr J. R. Hilditch and in collaboration with experimental archaeologist Dr C. D. Jeffra. For more information on the project, visit <https://tracingthewheel.eu/>.

to use new devices and software and placed an emphasis on the role of 3D modelling as a research tool, I did not critically question why and how I appropriated these new technologies into my existing practices. I was carrying out research to create scientifically informed 3D images and was using this technology to improve the results. Reflexivity was primarily reserved for a multivocal approach for involving and engaging the public (Opgenhaffen, Revello Lami, & Kisjes, 2018). Working alongside colleagues to analyse the ancient pots and past potting practices within the TPW project inspired me to reflect on the current archaeological visualisation practices as well, especially from the perspective of the digital 3D technology as a technological innovation. The framework encouraged me to critically assess my active role in the visualising process, starting as an archaeological illustrator but now operating as a visualising archaeologist. I also wanted to question the new digital 3D tools I use and their mutual agency in the entangled image-making and meaning-making processes. Was I still a visualiser within this project, or just a technician passively pushing the buttons? To what degree has my practice changed through the implementation of new tools? To what extent has the visualisation tradition in archaeology been transformed? Another, yet no less important, question is how these changing technologies and practices had affected the archaeological visual product, or whether it essentially remained the same. I use my personal experience as a case study throughout this article to show how the framework can be implemented within research. In the next sections, I explain the applicability of the chosen theoretical approaches, such as the *chaîne opératoire*, communities of practice and reflexivity, and how their integration towards a coherent methodology enables the community of archaeological visualisers to further reflect, assess, and document visualisation practice and the process of image making.

2.2 Approaching Technology with the *Chaîne Opératoire*

The *chaîne opératoire* is an analytical framework in which the technology of material culture can be compared to explain social processes. Within this multiscalar approach, the detailed analysis of the technical process is regarded as a meaningful sequence of performances and actions on matter to create a thing, 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, 2018; Lemonnier, 1993; Leroi-Gourhan, 1993). Whether Bronze Age potsherds are the object of study to identify technical acts left by the use of the potter's wheel by a potter in a certain locality a long time ago, or the creation of the digital reproduction in 3D of that same potsherd by an archaeologist with a 3D scanner to enhance the identification of traces left by those technical acts, the underlying mechanisms of making a thing remain the same. The *chaîne opératoire* conceptualises visualising archaeologists as making *choices*, a choice to adopt new technology and learn how to use it to enhance analytical practice, to retrieve more archaeological data, and, ultimately, to create new knowledge about past behaviour. The implementation of this approach offers a huge potential for identifying, describing, and assessing archaeological practice and changing traditions.

Technical knowledge is usually learned or transferred by watching and replicating the performative acts of others, until the gestures are internalised and become habitual. New knowledge is produced once new techniques and tools are introduced into an existing practice, such as the potter's wheel or the total station, which requires new types of gestures, actions, and adaptations of existing ones. These actions were first discussed by Marcel Mauss (Mauss, 2006 [1935]), who embedded techniques in a social context by separating them from the previously exclusive natural realm (Hilditch, 2020). Mauss's student André Leroi-Gourhan elaborated on this concept by seeing artefacts as extensions of the body, "meaningfully constituted through the results of sequences of gestures applied to material" (Audouze, 2002; Hilditch, 2020, p. 63; Leroi-Gourhan, 1993 [1964]), making technical acts simultaneously social acts. He called these series of actions *chaînes opératoires*, or operational sequences, an explicit technological approach to material culture. Although predominantly applied in prehistoric archaeology, the concept has been adopted increasingly in other archaeological specialisms as well in the last couple of decades. These studies demonstrated that objects are socially produced through a dynamic relationship between the social and the practical, with a specific attention for the sociality of the actions on matter and the bodily gestures involved in this process (Lemonnier, 1993; van der

Leeuw, 1993). The use of tools was increasingly considered as equal participants along with the techniques and bodily gestures (Roux, 2003), as well as conscious and unconscious decisions by the producer, or “technological choice,” which is fundamental in the technical process to explore the possibilities within the practice (Lemonnier, 1993; van der Leeuw, 1993 and others). Notably, Valentine Roux has successfully implemented the *chaîne opératoire* in ethnoarchaeological studies to ancient and modern pottery production to methodically identify which traces correspond to certain manufacturing methods and techniques, and through this reconstruct the inferred steps in the operational sequence. Considered together, the concept of *chaîne opératoire* “effectively links a rigorous and practical set of empirically grounded analytical methods with a robust anthropological theory of social reproduction” (Dobres & Robb, 2005, p. 163).

The importance of tools and decision making in the operational sequence of ceramic production and the distinction between techniques and methods are brought a step further in this article as the archaeologist’s digital tools play an increasingly integrated, almost invisible part in daily practice. The *chaîne opératoire* approach integrated within a reflexive, praxis-oriented framework allows more emphasis to be placed on the reciprocal relationship between archaeologists and digital devices. The introduction of new tools and technologies played a crucial role in Leroi-Gourhan’s study, connecting social and evolutionary processes with technological development. Moreover, he connected the human body to prosthetic devices, as external organs in the process of making things, with the bodily gestures performing actions on matter with the tools as extension of the body. Perhaps, archaeologists could perceive the tools they use for visualising material culture as a kind of prosthesis or mediator as well. If so, how do archaeologists act upon and respond to digital 3D technology, such as 3D scanners and 3D modelling software, when visualising artefacts? How do they adapt their practice and gestures and bodily movements with these intermediate machines and screens?

The idea of a prosthesis in relation to archaeological images as replacing something that has been lost or is absent has been explored briefly by Olsen et al. (2012, pp. 81–85), albeit restricted to images. Graeme Earl expanded this to the practice of making images itself, by seeing 3D modelling as “digital prosthetics” in which the process of 3D modelling becomes a bodily experience through repeated actions (Earl, 2013). These approaches tend to focus on either the digital things that replace something or digital tools being assimilated into archaeological (bodily) practice. However, they remain detached from each other, ignoring the intricate relationship between tool and archaeologist and how they shape each other. Research into the introduction of the potter’s wheel draws attention to issues of both potter and tool, such as how the posture of the potter adapts to using this new tool, as well as considering how novel production practices are created and adapted in response to this new tool, through their combination with preexisting forming methods such as coiling (the application of rotary kinetic energy, or RKE, to a preformed rough-out; e.g. Gandon, Bootsma, Endler, & Grosman, 2013; Roux & Courty, 2019; Roux & de Miroschedji, 2009). It is from this perspective that Monika Stobiecka rightfully states “[p]rosthetization is a process of mediation between technology and archaeology, where both components should be balanced” (Stobiecka, 2020, p. 346). The notion of digital 3D tools as prosthetics is here understood from a praxis perspective, following the study of Warnier (2001, 2009), more specifically as “the capabilities of these methods to work not only as physical, but also mental, extensions of our work” that enable “constructing strands of research, knowledge, and perception” (Chrysanthi, Murrieta-Flores, & Papadopoulos, 2012, p. 9). The tool, whether it is the blind (person) with their stick (Warnier, 2001, p. 7, after Paul Schilder’s *Körperbild*), the ballerina “merged” with her *pointe* shoes (Hoogsteins, 2013), or the archaeologist with the 3D scanner, is an integrated extension of the body. For the archaeologist, its material affordances have a direct impact on the archaeologist’s practice. The instrument as praxis is, therefore, a “situated dialectic of activity” that works in mutual directions, to the body and the machine, including its material agency (Malafouris, 2008, p. 33).

Innovation and invention take a central place in studies on technological change, and the concepts dovetail with the *chaîne opératoire*, which allows to identify the underlying mechanisms to assess *how* they occur. Technological *innovation* is the intentional or unintentional uptake and adaptation of an invention in an existing tradition, but it does not replace it (Guille-Escuret, 1993, p. 214; Roux, 2009, p. 217). A fundamental concept for considering innovation and invention is a technological choice, a process that also determines the appearance, function, and the sustainability of the product, be it a Minoan bridge-spouted jar, a Late Archaic Italic temple, a Philips air fryer, or a Wavefront.obj file extension. This choice for potential solutions to technical problems is usually limited by the tradition and inherent technical

know-how in which the ancient potter or modern archaeologist operates (van der Leeuw, 2008). When a technology originally designed for a specific tradition is adapted and embedded into a different technical tradition, a process of social negotiation starts due to the dissociation between the technical facts and the existing social facts (Guille-Escuret, 1993). New relations and associations in the community have to be made. The process of introducing new 3D technology into existing visualisation traditions and confronting other practitioners within the community, is still being negotiated and, in the process, its position within the archaeological tradition is still being determined, as Perry and Taylor have recently demonstrated for digital archaeology (Perry & Taylor, 2018). An *invention* occurs at an individual level within an existing system; however, it creates a new tradition (van der Leeuw, 2008, p. 242) and requires a strong stimulus and a need for technological change (Cresswell, 1993, p. 207) and is often limited by external environmental factors and is economically driven. An invention is “a break in the routine,” a creation of something new “that was absent before” (Lemonnier, 1993, p. 21). Although the potter’s wheel originated as early as the second half of the fifth millennium BC in the Near East (Roux, 2003; Roux & de Miroschedji, 2009), the transmission and uptake of the wheel as a technological innovation in other potting communities followed a different trajectory than that of the invention, hence not replacing the existing potting tradition. Sometimes, the offered technology was, despite its technological advantages, rejected wholesale due to unfounded social beliefs. Digital 3D scanners are an exciting technological innovation, but they have not replaced a whole tradition of visualising archaeological remains. The social organisation of visualising archaeologists, however, may have changed, as have some methods and gestures within the practice.

2.3 Communities of Practice

Making things, be it pots or 3D visualisations, do not occur in isolation but within a social context. A technical tradition reflects the identity of a social group, which is maintained and reproduced by transmitting technical knowledge and know-how to next generations of practitioners. The learning of techniques within socially embedded contexts relates to Pierre Bourdieu’s concept of *habitus*: the mental structure that becomes internalised in individuals through time within a given social context. *Habitus* structures the learned capacities to think and act in fixed ways, whereas the agency of individuals reflects and reproduces, simultaneously, the social structure (Bourdieu, 1977). These actions can be analysed to understand more about this learning process of individuals and the social groups they belong to. The concept especially addresses everyday material and intellectual embodied or “habitual technological routines” (Dobres, 2010, p. 110) of practitioners, allowing them to enroll into dedicated communities of practice and providing a sense of belonging and identity. The routines are the prerequisite for social reproduction (Wenger, 1998) and could help at least partly explain why particular traditions were successful and persistent, whereas others were ineffective and inconstant (Dobres, 2010).

The identification of these social groups, or communities of practice, is the next level of analysis of practices. The concept of community of practice was formulated by computer scientist Wenger (1998), who was building on an earlier study of anthropologist Jean Lave on “situated learning,” which can be understood as a form of socially embedded participation in the practices of these communities (Lave & Wenger, 1991). In other words, a community of practice is the locus where the learning takes place (Hughes, 2007, p. 31). This organisation is shaped by practical and social engagement, which consists of learning by doing through a shared experience, personal participation in social life, and producing (material and conceptual) artefacts (Wenger, 2010). It is through this dynamic and active, entangled process of engagement that any practice receives its meaning. The creative nature of making things also informs the construction of identities related to the community (Dobres, 2010). When an individual can operate outside the socially constituted system, this might – but not necessarily – cause a disruption of production sequences or research strategies (Wenger, 1998). This notion could shed light on how these communities have changed, and if their participation in certain activities (with new tools or technology) within those practices have transformed the social structure of the community. With this in mind, should we consider digital archaeologists as a community of

practice, distinct from a community of archaeological visualisers and visualising archaeologists using digital technology? Or is it one community of archaeologists sharing the same technical tradition?

These social behaviours are not only determined by their social context; they are shaped by the material and the environmental contexts too. The first step to unravel these socially embedded practices is by studying the decision-making process as sequences of acts and gestures and reconstructing the *chaîne opératoire*, by analysing in great detail the material remains, or ethnoarchaeologically by the digitisation process of artefacts. Each trace may reflect an act or stage in the operational sequence of a technician making a thing, and simultaneously, the analysis places the technician in a socially informed environment. When a new experience or technology is brought by a practitioner into the practice of a community, a process of negotiation starts whether to adopt or reject the new element. The new method or tool disrupts the existing *chaîne opératoire* and the social organisation that the practice reflects. As a consequence, the learning of a practice has to be realigned and as such the social organisation redefined. A balance between preserving the tradition and abandoning it to start something new is often possible when different communities of practice interact with each other and explore the boundaries beyond familiar practices. Beyond those boundaries, other social groups do learn and transfer things in another way (Roux & Courty, 2019). Artefacts, whether material or conceptual, real or virtual, receive a different meaning across that boundary, which is archaeologically interesting when the identification of networks of learning and technological transfer are the desired goals. According to Wenger (2010), learning a practice is not only restricted to learning new techniques but also about acquiring technical know-how and knowledge about the world in which this takes place. Technological boundaries are the identifiable results of that technical know-how and knowledge of a shared practice, and as such conform to social boundaries (Roux & Courty, 2019, p. 5). Technical traditions, however, can be so strong that they can coincide with social boundaries, making them more resistant to change than, for example, more easily transferable features such as aesthetics and style (Roux et al., 2017, p. 320). There is a striking relationship between techniques and identity because a technical tradition, or *chaîne opératoire*, is indicative for a tradition, an inherited way of doing things (Roux & Courty, 2019, p. 6) that expresses a social group within that larger tradition.

2.4 Engaging Reflexively with People, Technology and Material

Commonly used methods to investigate potting practice are experimental archaeology² and ethnography,³ of which the latter might prove useful to analyse visualisation practices. Although archaeologists are adept at applying ethnographic approaches to explain past and present cultures, Matt Edgeworth rightly noticed that archaeologists themselves are remarkably ignorant in explaining their own academic practices (Edgeworth, 2006). In his seminal edited volume on ethnographies of archaeological practices, Edgeworth proposed that archaeologists should instead focus reflexively on practices in both the past and present (Edgeworth, 2006). Almost a decade later, he explored through an ethnographic case study of how a large part of the archaeologist's research praxis and acts of discovery moved to the screen, and how these affected modes of perception. He noticed in this study that the archaeologist "is using embodied skills and multiple senses in physically engaging with the computer hardware" (Edgeworth, 2014, p. 54), indicating how

² In the TPW project, experimental archaeology is an integral part of the framework in which the experimental archaeologist reconstructs pots with different techniques and methods. The resulting traces left in the surface of the pots can then be compared with ancient traces to identify techniques and methods within an assemblage. Once the *chaînes opératoires* present have been reconstructed, they can be subsequently compared technologically with assemblages from other sites to discern connections among the communities. For more information on TPW's experimental methods, see <https://tracingthewheel.eu/> and Hilditch, Jeffra, and Oppenhaffen (2021). On specific experimental methods relevant to TPW, see Jeffra (2015a,b).

³ Anthropologists and ethnoarchaeologists have carried out ethnographic studies to contemporaneous potting traditions and communities in, for example, India (Roux & Corbetta, 1989), the Philippines (van der Leeuw, 1983, 2020), and Niger (Gosselain, 2015, 2016), which provides invaluable insights in technological processes.

displaced the archaeologist has become from the physical, archaeological material, or excavation. This ethnographic, introspective method combined with that of the *chaîne opératoire* could serve as a methodological device to shed more light on the murky visualisation toolkits of archaeologists and their intricate digital practices. Another ethnoarchaeological approach, as one might term it, is to reflexively map and analyse the current digital visualisation practice, in effect meeting Huggett's call for more introspection to digital practice (Huggett, 2015a), which is progressively becoming customary in archaeology.

The concept of reflexivity is ingrained in the work of Bourdieu and is closely associated with his concept of habitus, the fixed ways in which a person has learned to think and act, while simultaneously the agency of that person both takes place in and is inextricably bound up in that social world (Schirato & Webb, 2002). Practicing archaeologists are bound up in their observations of any given object as well, within a social structure, be it on an excavation or in a laboratory. The resulting archaeological knowledge is consequently biased by the social and material engagement with the object under study and the practices performed under particular research conditions (after Warwick & Board, 2013); in other words, there is no presupposed “distinction between subject and object” in archaeological research practices (Berggren, 2014, p. 6256). A reflexive approach to current, digital archaeological practice has indeed been advocated for more than 25 years (Berggren, 2014; Berggren & Hodder, 2003; Carver, 2006; Hodder, 1997, 2005; Morgan, 2016; Perry & Taylor, 2018; Tringham & López, 2001; Tringham, 2010), and it could be a solution to not only overcome this bias, but to gain a more profound understanding of the mechanisms underlying the uptake and transmission of new digital technology into existing archaeological visualisation strategies.

These previous reflexive studies are, however, typically focused on fieldwork practices, the transparency of data and workflows, defining a “computationally informed framework” (Perry & Taylor, 2018, p. 12), multivocality of interpretation processes, the democratisation of technology, the flattening of social hierarchies in the field, and giving a voice to different participants or “stakeholders” in the production of knowledge. Less attention was given to material culture studies outside the excavation context and the production of visualisations. These questions relate to processes of implementation of new technology and its ensuing procedures, the role of the visualising archaeologist in this process and associated issues such as the mechanisms behind the transfer of knowledge/technical know-how to a whole next generation of archaeologists – beyond “democratisation of technology.” Therefore, the formulation of a framework informed by practice, irrespective of which technology, as presented in this study, might be beneficial to all archaeological specialisms and subdisciplines.

Recent voices have raised the point that theoretically engaged discussion has taken place since digital visualisation tools were first introduced (Beale & Reilly, 2017b; Daly & Evans, 2006; Opgenhaffen, 2021; Perry & Taylor, 2018), but the bulk of studies are dedicated to technicalities and present case studies resulting in a “technical solutionism,” pushing the theoretically informed discussion to the background (Gordon, Averett, & Counts, 2016, p. 4). Other scholars still claim digital archaeology remains under-theorised, or that the gap between theory and practice is too large (Huggett, 2015a,b; Huvila, 2017; Lanjouw, 2016). Fortunately, most scholars do agree that a reflexive approach towards technology and practice can overcome this form of digital identity crisis. But how to proceed? How to perform “reflexive” research? Several reflexive research strategies have been developed over the years, most of them within the context of the Çatalhöyük excavations (Berggren, 2014; Berggren & Hodder, 2003; Berggren et al., 2015; Hodder, 1997, 2003, 2005; Tringham & López, 2001). The analytical framework that the *chaîne opératoire* approach provides could be an expedient addition to the aforementioned strategies, and can extend to reflect on practices outside the excavation context as well, such as material culture studies. The proposed integrated tradition in transition framework comprises all the aspects that “reflexivity” entails: technology, practice, agency, participants or stakeholders, tools, gestures, methods and techniques, knowledge, material, transmission, learning, interaction, and innovation. This reflexive reconstruction of the operational sequence of 3D visualisation may assist in locating the position of this community of 3D visualisers within the wider archaeological discipline, as meaning-making practitioners and contributors to the production of knowledge, with a firm embedded methodology that bridges method and theory. Ultimately, the integration of the two approaches into a new methodology bridges reflexive method with practice theory, enabling a critical awareness of the current practice to visual enquiry to the ancient material culture.

3 *Chaînes Opératoires* of Visualising Archaeologists

3.1 Visualisation Framed

Before going into detail on archaeological visualisation practice, it is imperative to clarify the distinction made between *chaîne opératoire* and life histories and biographies of objects. In this study and within the broader framework of the TPW project, *chaîne opératoire* is limited to the production and inherent creative practice and technical know-how. Consumption and repair are excluded from this methodology and TPW's overall theoretical framework, as they are concepts more commonly treated within the biography of objects framework. Consequently, this study considers the initial production of the 3D digital artefact but does not explore *subsequent* archaeological knowledge production generated by the 3D model beyond the producer.

Reflexive research on current practice cannot be understood without a clear idea of prior practice. What is more, a tradition is something that has undergone a long development and is being maintained and replicated over time, invoking a “persistent force driving the future” (Bronner, 1998, p. 69). To establish whether the tradition of archaeological visualisation has changed, or is changing into a fundamentally different digital 3D visualisation “tradition,” a clear understanding of practices beyond the processual paradigm is pivotal, which has been carried out elsewhere and on which some assumptions in this study are based.⁴ An historical survey carried out by the author showed striking epistemological similarities between early illustrations, nineteenth century physical models and current 3D visualisations, and furthermore demonstrated that the use of digital technology has only recently started to change how archaeologists reason and create archaeological knowledge (Opgenhaffen, 2021). Archaeology's visual tradition has not been replaced by the digital visualisation technology wholesale, despite the digital turn. After all, archaeologists still process largely the same data as those collected in a traditional fashion (Gordon et al., 2016), and these are interpreted from existing paradigms not yet tailored to technological progress (Rabinowitz, 2016). Most technology presented as something new is often rather old practice in disguise with ostensibly familiar looking outputs (Beale & Reilly, 2017a,b; Edgerton, 2008), produced from centuries old visual modes of representation (Moser, 2009). By comparing *chaîne opératoires*, we may assess alleged differences or similarities between archaeological (sub) disciplines and specialisms. In this section, two *chaîne opératoires* of analogue (anno 2005) and digital 3D visualisation practices with an emphasis on 3D scanning of artefacts (anno 2020) are recorded in diagrams, followed by visual analytical comparison (Figures 2 and 3).

Two graphic representations of practices developed by archaeologists Jill Hilditch and Sander van der Leeuw, respectively, are the foundations of the presented methodology. The first graphic is a table representing the TPW methodology as formulated by Jill Hilditch (Hilditch, 2020, Figure 2.1), and the second represents a set of diagrams of “network representations” created by van der Leeuw. Van der Leeuw illustrates here the complexity of ceramic production at different scales, from material procurement to workshop organisation, and includes the social context in which the potter works (van der Leeuw, 2020, Figure 13.1–7). The terminology associated with *chaîne opératoire*, for example, techniques and methods, follows the latest study of Roux and Courty (2019). The *chaîne opératoire* or “operational sequence” of archaeological (3D) visualisation can now be subdivided into five “events”: selection, preparation, creation, post-processing, and delivery.⁵ In this article, the sequences are understood and described as events in which a set of operations take place, as it combines the active nature of the enterprise with the element of time.

The entire sequence takes place within a social context, indicating not only that the visualisation is socially produced, but that social interactions during the visualisation process are authorising and

⁴ Substantial research into archaeological visualisation tradition has been carried out by Moser (2009, 2012, 2014), Moser and Gamble (1997), Perry (2009, 2011, 2015), Piggott (1965, 1978), Smiles and Moser (2005), and the author, who has recently attempted to unite the histories of digital and “traditional” visualisation practices (Opgenhaffen, 2021).

⁵ This terminology is, in turn, based on a unified terminology created by lithic specialists to enable comparisons between technical systems to support technological studies (for bones, ceramics, lithics, and metallurgy alike, and now digital technology; Roux & Courty, 2019, p. 41).

Figure 1: The visualiser's personal social remit, in which (unconscious) choices are made, and other participants such as apprentices and team members influence the decision-making process. Image by the author.

maintaining the community of practitioners as well. Consequently, the visualisation of an artefact starts with the engagement between people and material, with an archaeological specialist studying material culture and who requires a visualisation. Figure 1 represents the visualiser within their personal remit, with fixed aspects of the *chaîne opératoire* reciprocally influencing the visualiser. This remit represents the circles with the visualiser in the diagrams (Figures 2 and 3). These aspects are (by no means hierarchically ordered) **skills**, which are learned abilities that range somewhere between technique, practice and experience, and gestures, the unconscious, physical motor movements to operate a machine or to handle a pencil. Also, unconscious decisions are continuously taken and choices made, often but not always influenced by external factors and by engagement with the material itself. The element of choice affords or limits a certain way of handling and registration (on paper or on screen with a mediating tool), or associate socially with team members, students and other participants, or stakeholders in the process. Furthermore, there is a reflexive engagement between the participants, the material, and the tools here. For example, visualisers decide, based on their **technical knowledge** (*connaissance*⁶), which techniques and tools are available and what these tools allow to be done with the material. Simultaneously, material features, such as colour (black) and hue, and an extremely curved geometry of the artefact affect the recording device. Finally, every action and decision of the visualiser resonates in future events, which may result in the repetition of earlier operations. As a result, the boundaries between the events are not fixed, and the visualiser moves dynamically between the events.

3.2 Sequences in Action

3.2.1 The Event of Selection

In the first event (Figures 2 and 3), the selection of material by the archaeological specialist is directed by certain research aims, but also the affordances of the material and the tools chosen to visualise it, blurring the boundary of the next event, the preparation phase. Information deemed important is communicated by the specialist to the visualiser, who needs to have at least a basic understanding of the material to process it accordingly. The visualiser communicates the material limits to the specialist.

⁶ The *connaissance* of the visualiser, or maker, is a difficult translation. The best translation would be “know-that,” the mental scheme opposed to “know-how” or *savoir faire*, which is the physicality of that mental realm (Jeffra, 2020, personal communication).

Figure 2: The operational sequence of conventional archaeological visualisation in 2005. Image by the author.

Figure 3: The operational sequence of digital archaeological visualisation in 2020. Image by the author.

3.2.2 The Event of Preparation

The visualiser may choose to dedicate additional 3D scans to capture the important features of the object that the specialist pointed at with more precision. This choice may then lead to a higher density of vertices or increased resolution of at least part of the digital reproduction. Similarly, in an analogue drawing, these parts may eventually be highlighted with a pattern, stroke, or other coded convention. During preparation, the visualisation aims are composed of a range of decisions that depend on multiple factors, both within and beyond the borders of this event, and the technical knowledge of the visualiser. Working conditions such as place (a state-of-the-art laboratory or a creaky old building), natural or artificial light, and even traffic, all affect the visualiser's choice for the techniques, methods, and tools to execute the visualisation. A **technique** is the “physical modality” to transform the artefact into a visual product; in the present case, this is 3D scanning (Figure 2, anno 2020) and, 15 years ago, manual drawing (Figure 3, anno 2005). A particular **method** is “an ordered sequence of *functional operations* carried out by a set of elementary *gestures* for which different *techniques* can be used” (Roux & Courty, 2019, p. 41, emphasis original). The technique of structured light scanning (SLS) is governed by several methods, for example, the calibration procedure of a handheld Artec scanner is automatic, as opposed to the laborious calibration procedure of the DAVID SLS-3. In manual drawing, one can choose a method of pointing, lines or hatching, to indicate depth and details. Finally, **tools** can be either active or passive. Active tools are in this case the available brands such as NextEngine, Metashape or Cinema4D, Rotring pens, and template formers, but also ancillary equipment such as Lego bricks and other props to support the artefact, portable photo booths, and digital cameras. Passive tools are, for example, manuals, tutorials, or working plans.

3.2.3 The Event of Creation

Once the techniques, methods, and tools are decided, and concomitantly the visualisation and research aim and material affordances, the technical knowledge can be physically performed. In this creative event, operating procedures and series of actions and gestures assist in the execution of the visualisation methods. An **operating procedure** is “an implementation strategy of the *functional operations*” (Roux & Courty, 2019, p. 43, emphasis original), similar to a workflow. This set of gestures is, for example, the positioning of the scanner device (mounting the tripod with the metal bar, cameras, and projector), moving the handheld scanner around the artefact or the RTS prism pole around the feature, flying a UAV (also known as drones), software settings and parameters, and pencil strikes, handling the artefact, postures, and gaze (balancing above a grid tool or sitting in front of a screen). Actions involved in the method may include quality checks of the scans and observations made about the original artefact during the creative event.

3.2.4 The Events of Post-Processing and Digitalisation

In the event of the post-processing (digitalisation in 2005), the visualisation is further refined and enhanced with operating procedures such as running algorithms in analytical software, making objects manifold and watertight, simplifying models for presentational ends, exportation to multiple file formats, annotation of the models, and optionally converting 3D models into conventional 2D technical drawings. In 2005, this event encompassed scanning and digitalisation of analogue drawings in Adobe Illustrator or other image processing software, and placing a scale in the final technical drawing and, perhaps, adding supplementary information. The boundary with the prior event is fuzzy. Incomplete scans, or observations made while processing the 3D scans, may require additional scans or photographs. Actions such as communication with specialists and other participants or quality control may confront the visualiser with divergent expectations or standards of the specialist and other participants, forcing them to repeat the whole enterprise or even adapt certain methods to meet the demands.

3.2.5 The Event of Delivery

The final step in the sequence is the delivery of the visualisation to the specialist or participants. This act of sharing with participants depends on several other factors, such as storage space, online platforms and viewers, and copyright. Finally, quality checks of online presentation or paper proofs may cause excursions back to the previous events as well, as the resolution for both paper and digital publication may be too low, or publishers suddenly demand supplementary data.

3.3 Reflections: Transitioning Technical Traditions

The integrated descriptions of operational sequences from 2005 and 2020 are only possible because the division of operational sequences in the events of selection, preparation, creation, post-processing and delivery, have largely remained the same. One major exception remains: the post-processing event has replaced the digitalisation process (that had, in turn, replaced the event of inking). Layers of complexity have been added to each sequence, starting at the event of selection: the dimensionality and the geometry of the artefact complicate its capture by the digital apparatus, whereas this was less of an issue for analogue recording as there were codified standards to visualise the dimensionality and features. The adoption of the new digital 3D technology demanded new methods to visualise material remains, and heralded a wider range of techniques to choose from. The technical knowledge (*connaissance*) and know-how (*savoir faire*) of the visualiser expanded drastically.

The visual outputs have become more complex too, yet often simplified and reduced to familiar 2D images to be publishable. A truly new visual vocabulary has not been fully formulated, leaving the old visual formats in a state of transition. The starting point, the archaeological material culture, has however remained the same, yet new methods and techniques demand different research questions and adaptation of recording strategies of that material, whereas the visual products do not provide the new answers yet. The practice of highlighting has not changed in essence either and is now performed through a different method of recording and annotation of 3D models with tags. These tags visually direct the user through the model to places that are deemed important, similar to technical drawings, channeling directionality under the guise of “free navigation.” Certain methods may have changed, but crucial acts such as visual accentuation led to the conclusion that the practice of digital visualisation is still visualisation, similar to Steven Ellis’s statement that “digital illustration is illustration” (Ellis, 2016, p. 65).

The proposed methodology meets the prerequisites of data and workflow transparency that old charters and new initiatives have pleaded for but never managed to achieve. The reconstruction of personal or project *chaînes opératoires* allows a detailed recording of the decision-making process of the visualiser. Detailed descriptions of workflows comprising techniques, methods, operative procedures, and gestures during the visualisation process, i.e. the more generic operations that is, should be published online, for example, in blog posts and video tutorials.⁷ Particular operations such as specific settings to produce the 3D model, geometric properties, and particular contextual conditions that may have impacted the visualisation process should be recorded in object-specific metadata records. All files should comply with the FAIR principles to ensure reproducibility of visualisation procedures and subsequent knowledge production.⁸

3.4 Reflections: The Visualiser’s Position in Transition

Not directly visible in the diagram (Figure 3) is that the increasing number of participants with whom the visualiser collaborates and communicates, for example, drone pilots and geographic information system (GIS) specialists, have an impact on the social organisation of the craft. As a result, the role of the digital

⁷ For example, this blogpost by the author: <https://tracingthewheel.eu/article/workflow-series-sls-with-david>.

⁸ The FAIR Principles are a set of guidelines which intend to improve the Findability, Accessibility, Interoperability, and Reuse of digital datasets (Wilkinson et al., 2016).

visualiser has moved from a marginal to a more central and prominent position within research projects, and visualisation has concurrently become an integrated research method, instead of an auxiliary activity and final product.⁹ Even though the visualiser is invisible in the digital image, they are virtually present in the recorded metadata, in which ideally technicalities, observations, and the decision-making process are kept. This is contrary to the “old” practice of technical drawing, in which the decision-making process is usually not recorded, as if data transparency is considered unnecessary because the illustration is the data. The integrated role of the visualiser in research suggests that digital 3D visualisation is an archaeological practice, and the makers constitute a community of practice within the wider social structure of the archaeological discipline.

The “old” practitioners continue to collaborate alongside the “new” participants in the same social (academic or commercial) environment, and often have adapted their skillsets to new techniques. As a consequence, the role of the visualiser within the wider archaeological tradition is changing. Technical traditions may be explained in terms of learning modalities, as techniques are learned and transmitted within a social environment. However, the diagrams do not show where and in what context the digital 3D technology has been developed and how it came into contact with archaeology. Usually, hardware and software are not specifically designed for archaeology, but find their way into archaeology anyway through either interdisciplinary collaboration, the employment of external technicians or autodidactic experience. The latter option is suggested by the diagrams, which indicate the flexibility of archaeological visualisers to adopt, adapt, and deploy new technology into their familiar practices. Illustrators adopted and internalised the lithograph, graphite pencils, watercolour, the T-section, tracing paper, theodolites, total stations, Adobe Illustrator and AutoCAD, and the Wacom. In the 2000s, 3D modelling packages and computing power became increasingly accessible and affordable, and low-budget and user-friendly 3D scanners, as well as very expensive devices, appeared on the market, in addition to open-source codes for Structure from Motion (SfM) and SLS applications. With an already established digital framework, these new techniques were relatively easy to learn with a certain familiarity. Finally, digital visualisation techniques are increasingly part of the archaeological curriculum, yet often at the expense of traditional recording and illustration methods, and the consequent risk of deskilling and loss of knowledge has been feared by some (Caraher, 2013, 2016; Morgan & Wright, 2018). Nonetheless, new skills are learned and practices adapted, which ideally produce new knowledge and simultaneously reconfigure the community. Although the mastering of a new technology in the early days was reserved to highly specialised technicians of mystical allure, the open-source and DIY movement led to a democratisation of technology and a tendency to flatten traditional academic hierarchies, specifically within the communities of practice of digital archaeologists. Further research along the proposed line could determine the position and define the identity of the archaeological illustrator and visualising archaeologist in the new digital archaeological landscape.

3.5 Illustrating the Application of the Framework

3.5.1 Expanding Personal Skills and Know-How

Further research should be carried out to compare *chaînes opératoires* on a macrolevel to retrieve a full understanding of the current practice, but a start can be made on a microscale by an autoethnographic analysis of my own changing practice. As an archaeologist with a classical training in fine arts, I became equipped with visual techniques derived from the arts, which I then sought to apply to archaeology. Early stratigraphic drawings on a site in Greece were much appreciated for their aesthetic quality and found their way into frames on the wall in the study of the professor, but not into the publication. They were considered “too realistic.” It turned out that my artistic visualisation methods could not be transferred unproblematically

⁹ Of course, traditional illustrations and illustrators are considered pivotal to research, for example, by General Pitt-Rivers and Sir Mortimer Wheeler, or Alan Sorrell and Piet de Jong, but these are rather the exception than the rule, unfortunately.

into archaeological visualisation practice. After subsequent training and gaining experience in archaeological illustration, I adapted, but not fully assimilated, my artistic skills to archaeological visualisation practice. I then realised that I was more able to express and emphasise in an effective way thoughts and observations with 3D visualisation technology (Ribes, 2014), albeit within existing conventions and scientific expectations.¹⁰ This technical knowledge assembled over the years enabled me to adapt relatively easily to a new device or piece of software, as well as turning this into know-how of methods and operative procedures. After experimenting and learning by doing with scanning technology (Figure 4), I developed specific methods and operative procedures tailored to specific tasks. Gradually, peripheral technology became subsumed into the *chaîne opératoire* of visualisation, skills expanded and the practice extended, to be finally transferred to other academic research projects¹¹: the TPW project.

The section below describes the process of my visualisation *chaîne opératoire* as applied in the TPW project and follows the events in the diagram (Figure 3).

Event 1: Selection

The TPW team works closely together. The team members point me to forming traces left on the surface of ceramic vessels – hard to discern with the naked eye – which should be captured in high resolution by the 3D scanner.

Event 2: Preparation

In response, I inform my colleagues about the affordances of the ceramic material upon the SLS 3D scanner and vice versa, so that the selection of material is also tailored to the technology.

Event 3: Creation

So far the initial material interaction with the original artefact, as it swiftly shifts to an intimate relationship between the stationary scanner and the digital artefact as the scanning proceeds. During this creative event, I become completely distracted from the artefact while scanning, wholly absorbed by almost mechanical operating gestures and motor habits, and responding to circumstantial events interfering with the scanning session. The handling of the original artefact is in the service of the machine and the visuals on the screen. The procedure has become a completely disembodied practice with regard to archaeological material, and becomes replaced by an embodied practice with the digital device. This is contrary to the practice of manual drawing, where I would have had an intimate, tangible experience with the artefact and could have made direct observations.

Event 4: Post-processing (or digitalisation)

Despite the seemingly perfunctory interaction with the 3D model on the screen, new data about the original artefact is revealed as well, whereas in manual practice, observations were made in the earlier event. In doing so, the scanner is not an extension of the body as the pencil is to my hand, but rather a prosthetic to the pencil; the operative procedures and gestures with the instrument make 3D scanning an embodied practice and as such a valuable “cognitive artefact” in the creation of archaeological knowledge (Huggett, 2017).

Event 5: Delivery

The process of scanning and processing is minutely recorded as metadata in a spreadsheet, and together with several exported versions of the 3D artefact, entered into the database and made available online for future use and public display. Together with the specialist, the 3D model is tagged with information about the artefact.

Breaking the visualisation procedure into events enables us to analyse in detail the actions, choices, and bodily gestures involved. The example of the autoethnographic analysis of my own practice has demonstrated to what extent the introduction of the 3D scanner affects the visualisation practice and forces even the body to adapt. Just like the pencil and the potter’s wheel, the 3D scanner functions as an extension

¹⁰ Huvila and Huggett (2018) pointed out that the choice to adopt a particular technology depends on a wide range of scientific reasons and political factors that are often not made explicit. Initially, from a commercial point of view, I incorporated 3D scanning technology to enhance recording strategies, to more efficiently produce images and, from a scientific perspective, to use the 3D models as a base for more accurate 3D reconstructions of fragmented artefacts.

¹¹ For example, with technical and research articles, such as Opgenhaffen et al. (2018) and Revello Lami, Opgenhaffen, and Kisjes (2016).

Figure 4: Acquiring skill. One of the first scans with the DAVID SLS-3, and one of the most recent, with more details visible. Image by the author.

of the body and is operated on an automatic, almost subliminal level. The digital device is a prosthetic of our previous tools and not of the archaeologist, and in relation to the body, I proposes to regard it as an orthotic instead. Orthotics do not replace something that is no longer there, but reinforce something not fully functioning and enhance (bodily) functionality and performance. The 3D scanner enhances the visibility of macrotraces in pottery, and its visual output is much more versatile than its analogue counterpart, the pencil and the technical drawing. Digital orthotics enhance archaeological knowledge-making and by no means “self-amputate” (Chrysanthi et al., 2012, p. 8) or deskill archaeologists (Caraher, 2013, 2016) as a consequence of its assumed automation of traditional practices. However, they are complementary yet impose new forms of interaction and demand a new set of skills and know-how. The concept of bodily extensions and orthotics has been briefly touched upon in this study, but needs further investigation to determine how this impacts creative practice and to establish their role in shaping the visualiser’s identity as archaeological illustrator or visualising archaeologist.

3.5.2 Transferring Technical Knowledge and Know-How

Students, or apprentices, are important participants in the TPW project and play a central role in the reproduction of a practice. The student is taught the *connaissance* or theory behind the visualisation strategy with manuals and tutorials, but there is only so much you can verbally transmit of a largely embodied practice. Similarly, ethnoarchaeological research has demonstrated that artisans often cannot explain their practice in words, and offer “to show” it instead. The student starts learning once she puts the theory into practice and truly “incorporates” the learned skills (Roux & Courty, 2019, p. 4). Subsequent comparison of the visual products of the skilled archaeological visualiser and the student determines if the skills were transmitted successfully. Transmitting the practice is an interactive enterprise, in which both the tutor and the apprentice are participating in the reproduction and continuation of the practice, which shall be demonstrated by two examples.

Research master student Nina wanted to study specific shapes of Minoan pottery and TPW needed assistance in the processing of 3D scans. She was not able to study this material on location, but in this case, the unprocessed 3D scans could serve as digital surrogates. Nina was not particularly interested in the technology and had only basic digital skills. Nonetheless, it provided her a unique opportunity to learn about this material in great detail, by means of the alignment and processing of the 3D scans. She learned to use the scanning software by following the detailed instructions of the manual and receiving *ad hoc* help from the visualiser, usually by “showing” the solution. And indeed, while learning by doing, Nina, as she expressed herself, became intimately acquainted with the archaeological material. She then could connect her literature study of the archaeological context with the models by using the annotation functionality in Sketchfab.¹² This interactive practice, however, did not change the social organisation of the TPW team, as

¹² TPW’s 3D models on Sketchfab can be found here: <https://sketchfab.com/tracingthewheel/models> (last accessed 29 December 2021).

Figure 5: Online training, assessment, and feedback to Kelly by the author. Image by the author.

the original student–teacher hierarchy remained the same, but the structure of educational knowledge transfer did indeed reach a new level.

Digital archaeology master student Kelly reinforced the TPW team as a project-assistant to help with the 3D scanning of the project’s experimental ceramics.¹³ Kelly was trained in the TPW workflow by working through the manuals and tutorials while 3D scanning. Due to the COVID-19 pandemic, assistance and the assessment of raw 3D scans took place online (Figure 5). Kelly scanned and processed two dozen vessels and produced 3D models with a fairly consistent output that reached almost the same resolution as the skilled operator who devised the workflow and wrote the manuals (Figure 6). Because the author developed these, she could assess the quality of the 3D models and the student’s performance. Kelly has been trained in recognising the important technological traces herself by the experimental archaeologist of the project and has gained a profound understanding of the physical material as well. In doing so, her technical profile can be traced in the digital artefact, which resembles that of the members of the social group (TPW; Jeffra, 2015a, p. 142). Kelly can now transfer her acquired skills as a trained visualiser to other participants within this community of practice, or as a pottery specialist studying ancient technology. The digital 3D visualisation practice has diffuse boundaries and could potentially be transferred to other communities of practice. By studying the performances of particular *chaînes opératoires* of archaeologists, such as those of Kelly and the author, archaeologists can trace how those performances (of individuals) become “enmeshed within a network of dynamic relations” of archaeologists and other disciplines (Hilditch, 2020, p. 67). To trace this, to move between these scales, or to “zoom in or out” between practices (Huvila & Huggett, 2018), more reflexive ethnoarchaeological studies should be carried out, in which the proposed tradition in transition framework can provide direction.

4 Discussion and Summary

The tradition in transition conceptual framework is designed to assess and document archaeological visualisation practices of artefacts of archaeological visualisers/illustrators and visualising archaeologists, but its flexible structure could be expanded to other specialisations and material categories. The

¹³ These ceramics are produced by experimental archaeologist Dr C. D. Jeffra, who is also actively engaged in *chaîne opératoire* research on ancient forming methods.

Figure 6: Comparison of models of (left) the author and (right) the apprentice. Image by the author.

methodology can help to determine the position of the community of archaeological visualisers using digital 3D techniques in the chain of archaeological knowledge production. The aspect of learning takes an integral part in the identification of a technical tradition and its reproduction of a social group, this community.

To summarise, the tradition in transition framework comprises the following core topics, aims, and preliminary results:

Aims and topics

- The framework serves as a methodological implementation of the London Charter and Seville principles, complemented with the FAIR principles.
- The framework integrates the *chaîne opératoire* approach with reflexive theory.
- The maker, but also material agency, takes a key position in the methodology: a co-creative effort of machines/things and humans, as opposed to a technocentric focus on digital tools.
- The framework creates critical awareness with the visualising archaeologist or the archaeological visualiser about the adoption of and interaction with digital 3D technology.
- In the framework, learning takes a central place.
- The framework helps to position the visualiser in the construction of archaeological knowledge.

Preliminary results

- The pencil and 3D apparatus are extensions of the body, or even prosthetic. The visualiser is hardly aware of its presence, but the tool is enhancing (bodily) functionality and visibility of hidden material properties.
- Reflexive analysis demonstrates that bodily gestures and mental choices have moved away from the artefact and are now directed to the operation of the machine and the screen. A new form of material interaction with the artefact has developed. New insights are generated by an intimate relationship with the digital artefact and software to process and enhance geometric properties.
- The *chaîne opératoire* diagrams show that new skills, *connaissance* and technical know-how, entered the events of creating an image. One event in the chain has been changed already, but the technical tradition has not yet been replaced completely. It is in a state of transition.

By drawing on personal experience as an archaeological illustrator and visualising archaeologist, the author has demonstrated how the conceptual framework can be implemented in research. The examples and diagrams show that the technical tradition of archaeological visualisation has not yet essentially changed, as the events have remained largely the same, but layers of complexity have been added. The tradition is in transition, as increasingly digitally literate students will further refine the technology and eventually cross social boundaries of older generations and eventually break the tradition. Only then truly new knowledge will be generated.

5 Future Directions for a Tradition in Transition

The preliminary and introspective analysis of the *chaîne opératoire* of digital 3D visualisation leaves many questions open to further exploration. The 3D apparatus as an extension of the body, as orthotic or *Körperbild*, has been briefly interrogated, but a full understanding of the transition from the pencil to the 3D scanner and the coaction between the visualiser and the scanner have only been cursorily touched. Moreover to what extent does the machine or software dictate how the archaeologist proceeds and carries out research? The personal example showed how the 3D scanner already dictates part of the selection of artefacts. How powerful is the traditional archaeological gaze towards 3D images? How does this directionality affect our ways of interpreting archaeological material? Further research carried out along the scheme provided by the tradition in transition conceptual framework could give pointers to the impact of machine agency on archaeological interpretation. Beyond this is the important issue of the dichotomy between subjectivity and objectivity that digital technology tends to enshroud. Nevertheless, the issue is inherently present and treated implicitly when analysing a *chaîne opératoire* due to the central role of agency. Further, the practice of “pointing” or highlighting parts of the artefact and other subjective engagements between participants runs counter to the often-made claim that digital techniques are objective because the translated data is “filtered” by human and material agency, “and according to individual agendas” (Rabinowitz, 2016, p. 511), irrespective of the technique. The present study acknowledges the subjective nature of visualisation and the practice of subject making, and further elaboration with the proposed framework can explore this dichotomy in more detail.

The archaeological tradition of visualising the past is in a transitional stage. Digital technology has not fully replaced conventional practice yet, and visual outputs look remarkably familiar, as they follow a centuries old visual formula (Moser, 2009). The fundamental events that draw up the series of actions to produce a visualisation have largely remained unaltered. Certainly, the *chaîne opératoire* has expanded with additional layers of digitally complex methods and operative procedures, and archaeologists and technology alike have adapted to the practice. This increased complexity is mirrored in the social organisation of the work environment as well, as more agents participate in the creation and visualisation of archaeological knowledge.

More ethnoarchaeological research into visualisation activities and reflexive analysis of archaeological practice is needed to obtain a better understanding of how visualisation strategies have transformed or are in the process of conversion. A performative approach to the creative social enterprise that archaeological visualisation comprises has proved to be a valuable heuristic solution to disentangle the inner machinery of a community that has always endeavoured to improve its visual products. The tradition in transition conceptual framework integrates praxis-theory with a reflexive approach and aims to provide the building blocks to reconstruct the operational sequence of a practice in the past and in the present. The inherent multiscale approach enables us to move between personal workflows, networks of communities of practice, and the wider archaeological discipline as a whole, ultimately defining the position of digital visualisers within the discipline. The framework is especially designed to serve as a methodology to introspectively guide the application of digital 3D visualisation technology in research and to document the technical and decision-making process of the archaeological visualiser, permitting full transparency of practice and technology.

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