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Research Article

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Skeuomorphism in Digital Archeological Practice: A Barrier to Progress, or a Vital Cog in the Wheels of Change?

Abstract: This article focuses on the role of "skeuomorphic technologies" and "skeuomorphs of practice" in the development of digital workflows in archeology, seeking to examine whether there are common trends toward skeuomorphism in our development of digital infrastructures. By considering the way in which GIS, tablet, and 3D technologies were integrated into the digital field recording at the sites of Çatalhöyük in Turkey and Kämpinge in Sweden, we argue that skeuomorphic emulation may form an essential part of the process of "controlling" "socializing" new digital technologies and ultimately transforming digital practice. Ultimately we contend that a field approach that explicitly takes into account skeuomorphism as a crucial element of transformation is more likely to encourage the development of practices, which go behind the traditional investigation paradigms. Understanding the role of skeuomorphism as a mode of socializing technology (see below) within the broader framework of the development of digital field practices can help us to critically address the process of transformation of practice and identify new methodological directions.

Keywords: archaeological method, digital archaeology, skeuomorphism, 3D, archaeological recording

1 Introduction

This article defines and discusses the role of skeuomorphism within the context of digital archeological practice, and specifically, it focuses on the ways that the use of digital technology affects the epistemological processes associated with the fieldwork. In doing so, this article examines whether common trends toward skeuomorphism in digital structure and practice may form an essential part of the process of "getting to grips" with new digital technologies and shape a conceptual framework for this process. This article draws upon the authors' experiences of developing digital field workflows at the sites of Çatalhöyük in Turkey and Kämpinge in Sweden.

Archeological investigation methods are the result of years of experiments, developed for identifying efficient recording practices. These methods are usually designed using the technology available at that specific time and are arranged to serve conceptual frameworks, either explicitly or implicitly created for

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identifying and analyzing the various evidence encountered during the investigation. The definition of such practice shaped the discipline as it is today and indirectly provided archeologists with rules on how the information should be searched, grouped, and used for supporting archeological interpretations. In the field our philosophy and practice of excavation tends to crystallize into a set of rules that are represented in our recording systems (single context recording, lot and loci, planar recording, etc.; see, e.g., Pavel, 2010), our on-site and postexcavation protocols, and our paper/permatrace (analog) and digital data structures.

Modifying such practice impacts the entire investigation process, and hence, the introduction of new instruments and methods for recording and managing archeological data has always been a complex issue, which affected at the same level both theory and practice. In case of projects that are not "born digital" (like Çatalhöyük), the process of digital "transformation" of field practice can be difficult, but equally those projects that are conceived and born digitally (like Kämpinge) face the challenge of making their digital approaches mesh with our existing disciplinary philosophies of practice and preconceived concepts of "what an excavation should be." None of this is easy.

This article considers the process of introducing 3D visualization technology within archeological field practice through the lens of skeuomorphism. Specifically, by reviewing the work developed during field investigations carried out across different research projects, we review the impact that 3D recording and visualization technology had within the daily investigation of these projects and consider how the process of *socializing* new and emergent technologies by skeuomorphic *emulation* of both technology and associated practice leads to a robust critical experience, which ultimately *transforms* field practice.

To situate these transformative processes within a wider understanding of changes in our engagement with digital technologies, it is worth considering Buccellatti's (2017) focused discussion of what he sees as a modern disciplinary shift toward digital thinking or "digital thought." He essentially argues that, as new technologies become ubiquitous in everyday life (i.e., we become more familiar with them, more surrounded by them, more trusting of them, and ultimately, imperceptibly more reliant upon them without necessarily understanding what is going on "under the hood"), we begin to understand their potential *before* we fully perceive their structural implications upon society. This preliminary understanding he labels "para-perception," the intuitive act of transformatively realigning our "mental templates" to allow us to think about technologies differently, which ultimately allows us to absorb a new (in this case, digital) "mode of thinking" (ibid., pp. 172–173). We would suggest that both "technological skeuomorphs" and "skeuomorphs of practice" are essential to cultivating "para-perception" in digital thought.

2 So What Is Skeuomorphism?

In general terms, "skeumorph" refers to "*the imitation of a shape or a decorative technique in another than the original material*" (Löbbing, 2015, p. 105). This terminology is often borrowed within the context of digital technology design and development for describing virtual or physical interfaces that imitate the appearance of real objects, and from a technological evolutionary perspective, skeuomorphism is considered an important process in the introduction of new materials and technologies (Frieman, 2013, p. 319). It can be argued that the spread of new digital recording and visualization technology for managing archeological information has generally been adopted with the explicit aim of improving on traditional methods, and one of the net results of this has been that digital technologies often deliberately imitate more traditional methods in their application. For example, GIS and CAD systems were often used for producing digital maps and sections, and total stations or GPS was initially employed in the field for general topography, and digital photography obviously emulates its analog counterparts (indeed the dramatic increase in the number of digital photos which can be, and are taken, is arguably the most widespread impact of digital technology on excavation fieldwork practice). We would suggest that rapid and ubiquitous adoption of these "stealthy" (in that they are often adopted seamlessly) skeuomorphs has been so successful because they are (with very little need for development) completely recognizable within the existing field of practice;

they are not scary, they are easy to understand and have comparable existing outputs (in this sense, they are already "*socialized*").

So in order for a new and emergent technology to be readily acceptable, it needs to be comprehensible to practitioners and produce something useful within the field of practice. On the one hand, the introduction of these instruments within a robust (and well established) field of practice allows for the testing of the limits and potentials of new digital tools; on the other hand, restrictions imposed by the same practices could also limit and constrain the capacity of such tools for exploring and expanding methods or innovating practice. This may be counterproductive if one wants to explore the potential of new and emergent digital technologies to change the ultimate aims and outcomes of the established field practices. Indeed, since the creation of knowledge in archeology is intrinsically linked to our capacity to perceive the archeology itself, which in turn is reliant on the media and technologies we use to record it, understanding and embracing changes in this technology must be critical to the discipline.

Taylor describes skeuomorphism as a process of imitation performed when people are unable to cope technically or conceptually with new materials (in Frieman, 2013; Taylor, 1999). In a very similar way, we contend that the introduction and the use of digital recording instruments in the field were initially limited to perform operations, which emulated, more than improved, analog practices (even if perhaps the end goal was to innovate method). Rather than being direct "technological skeuomorphs," we would call these "skeuomorphs of practice." For example, in the process of digitization of hand drawings of maps and sections made on-site, analog versions were transformed into raster files and later used within computer programs as a reference to generate digital polylines and polygons. Often these digital drawings were printed and used like their originals for revising the investigation process and for supporting discussion, and ultimately the print output of this process in post-excavation and publication was the same as their analog equivalent (a compiled phased plan or map of the site). As the digitization of analog archives became more commonplace (since the 1990s), the advantages connected with digitization have become more linked with aspects of reproducibility and storage (of the physical analog archive) rather than necessarily improving the quality of the interpretations (see, e.g., Hopkinson & Winters, 2003; and discussion in Morgan & Wright, 2018, pp. 142–145).

From the perspective of modern design trends in usability and user experience, when a new object is introduced in the market, a mimetic approach is used for helping people to create mental models based on earlier experience (Bonelli, 2016, p. 309). If these mental models frame our behavior, then we can argue that artifacts and behaviors are interlinked (see Knappett, 2002, p. 100). As Huggett (2017, p. 1) underlines, by understanding how new technologies affect us, we can start using them for developing innovative new ways of thinking. We would argue that a field approach, which explicitly takes into account skeuomorphism as a crucial element of transformation, is more likely to encourage the development of practices that go behind the traditional investigation paradigms. Understanding the role of skeuomorphism as a mode of *socializing* technology (see later) within the broader framework of the development of digital field practices can help us to critically address the process of transformation of practice and identify new methodological directions.

In addition, Knappet describes skeuomorphism (within an archeological context) in the creation of artisanal objects (artifacts) as a practice used for gaining influence over the original material. By *imitating*, the artisan exercises control over the original and the whole network of users (Knappett, 2002, p. 111). In a similar way, in terms of introducing digital tools to our workflows (for creating "digital artifacts"), by transferring part of the functions usually assigned to traditional (analog) tools onto new (digital) instruments, we impact the work of field practitioners (our "network of users"), ultimately bringing substantial changes in their practice. Despite common arguments to engaging with digital technologies in the field revolving around efficacy or efficiency from those who understand the technology, the shift from analog to digital practice in this case can be often resisted in the first instance by people (team members, professional archeologists?) who lack the digital expertise, training, and experience to work with new digital tools, on the basis that it does not really add anything meaningful to our practice ("if it ain't broke, why fix it!?"). We would argue that in these terms, the process of skeuomorphism in digital practice plays a crucial role in the "socialization" (i.e., disciplinary acceptance) of new and emergent digital technologies.

As we have shown in archeology, skeuomorphism is often discussed in relation to the adoption of new technological practices and materials within prehistoric societies, and across the years, several theories concerning the way skeuomorphism impacted innovation and production were formulated. Despite the different perspectives proposed so far, all applications of the concept reference the way in which new technology is utilized to "create things," and there is a general consensus in recognizing an important role of skeuomorphism within the development and diffusion of new practices. Therefore, understanding the role of skeuomorphism in this process ultimately has something to tell us about social and technological change rather than simply whether one tool is better, newer, or more efficient (Frieman, 2013, p. 323).

3 Skeuomorphism of Practice

Despite the considerable development and the diffusion of digital technologies within archeology as a discipline, the so-called "Digital Turn" (Costopoulos, 2016), with the exception perhaps of survey equipment, the presence of digital instruments to support field operations has always been minimal, with the majority of digital instruments and tools (including both hardware and software) mainly employed during post-excavation activities (e.g., GIS, CAD). The reasons for their limited diffusion in the field can be due to the following multiple factors:

(1) initial obstacles in verifying the quality of the dataset against the archeological evidence;
(2) the complexity of the technology requires a degree of technical expertise to operate;
(3) tendencies for nonintuitive interfaces in early software development, which make it difficult for "lay-persons" to explore and experiment; and
(4) difficulties in introducing new methods within well-structured excavation routines (projects, organizations, individuals often resist what they see as "change for change's sake" when current "traditional" practice is deemed fit for purpose).

The introduction of such technology affects our relationship with the materials encountered during the investigation (Huggett, 2017, p. 1), and hence, shifting from analog to digital should be a matter of intense consideration (Morgan & Wright, 2018, p. 147). However, this transition should not be feared, but regarded as a natural process for reaching new forms of interactions with the materials encountered during the investigation.

Again, with the exception of total station theodolites and digital photography, the construction of sophisticated workflow pipelines based on multiple digital recording tools for documenting archeological evidence in the field occurred only recently. If we focus upon the relatively recent (post-2009?) and fast-paced development of 3D image-based modeling techniques combined with the diffusion of efficient visualization systems and portable computers, we can see very clearly that this suite of digital technologies has triggered an intense phase of experimentation in recent years, which has led to the definition of a number of different applications and solutions (Callieri et al., 2011; Dellepiane, Dell'Unto, Callieri, Lindgren, & Scopigno, 2013; De Reu, Trachet, Laloo, & De Clercq, 2016; Forte, Dell'Unto, Issavi, Onsurez, & Lercari, 2012).

Early on in the adoption of these 3D techniques, their earliest coherent integration into archeological field practice (beyond "blue sky" experimentation) tended to center upon the "emulation" (of traditional methods) and efficiency seems to have been one of the driving motives for their introduction in the field (see, e.g., Doneus et al., 2011; Galeazzi, 2016; Lerma, Navarro, Cabrelles, & Villaverde, 2010; or McPherron, Gernat, & Hublin, 2009) It could be argued that a lack of understanding of emergent technology at a disciplinary level means that it can be hard for the wider discipline to connect to and innovate with "bleeding edge" technology. In particular, those parts of the discipline that are associated with particularly well-established fields of practice (long-term research projects or the commercial sector) when exposed to new digital technologies display, at worst, a tendency to resist its adoption with a dogmatic air of "stick to what you know" (often couched in vague arguments centered on the cost of implementation, or lack of training, or that the technology "doesn't bring anything new to the table"); or where new technologies are

deployed, they simply tend to emulate existing workflows as a form of both "skeuomorphic digital practice" and skeuomorphic digital assets (outputs, data structures, etc.). It is in fact this latter issue of skeuomorphic digital practice that we would like to explore in the remainder of this article.

It is interesting to note, for example, that very few critical assessments were presented early on in the disciplinary adoption of emergent 3D digital technologies concerning the way they impacted practice. As the suite of 3D technologies matured and became more commonplace (and accessible), scholars began to discuss the effects that these techniques were having on the social and cognitive dynamics, which characterized the field investigation (Berggren et al., 2015; Caraher, 2013; Huggett, 2017; Morgan & Wright, 2018; Taylor et al., 2018). Over time, several sessions within the frame of international workshops and conferences, e.g., CAA, SAA, EAA, or TAG, started focusing on the impacts that 3D methodologies were having on current archeological theory and practice. These discussions centered upon various issues linked, for example, to the affordances of digital methods in archeology (their potential and limitations as a discrete set of technologies), how they are changing practice in the field, and critically how they were both reinforcing and impacting analytical approaches to visualizing archeology and disciplinary modes of knowledge production. Such dialogue has helped to "socialize" these new methodologies to the wider disciplinary community, encouraging further experimentation and developments of new practices.

Over (a relatively short space of) time, 3D technologies (and their digital outputs) started to be used as "boundaries models," namely objects which, as defined by Star and Griesemer (1989, p. 393), can be used across several intersecting social worlds (e.g., *field practitioners, disciplinary specialists, the public and other stakeholders*) and that have the capacity to satisfy the informational needs of each of them. 3D recording and visualization technology began to be used in the field to produce datasets capable of serving different communities of researchers (Campiani, Lingle, & Lercari, 2019; Wilhelmson & Dell'Unto, 2015); and in the same way that skeuomorphism facilitated in the past socialization with new technologies or materials (Gošić, 2015, p. 730), it would seem that a tendency toward mimetic skeuomorphic digital practice (emulating earlier analog traditions of practice) over the last decade or so has to help to ease the integration of 3D digital technology into the field, making the transition between practices easier.

The datasets produced as a result of this integration followed a similar "socialization" process. 3D models were initially used for extrapolating bidimensional images used to substitute traditional graphic datasets (sections and plans). By engaging with these data, archeologists had the chance to assess the limits and potentials of 3D models gaining control over their real affordances. Such knowledge allowed the integration of 3D dataset within the rest of the documentation opening new opportunities for expanding practice.

By following our own experience of introducing these new instruments in long-term field projects, and in the process of engaging with these datasets in the field, in this article, we analyze and discuss the relationship of "skeuomorphic practice" through three specific phases of technological development in these projects: "*Emulation*" *of existing practice* (Phase 1), "*Socialisation*" *of new* (*digital*) *technologies* (Phase 2), to a final "*Transformation*" of practice (Phase 3) (Figure 1).

We consider these phases as part of an ongoing process and as a way to describe the development of digital methods in archeological field practice. It is worth noting that this process is not the only mechanism for organizational (or disciplinary) change through the introduction of new technologies. Many of the problems outlined here are well known and documented across many domains impacted by the tech industry both within the Heritage Sector more generally (see, for example, Peacock, 2008) and more widely in the industry (Gölzer & Fritzsche, 2017). The model of transformation of practice by skeuomorphic socialization proposed earlier might, for example, stand in direct contrast to the so-called disruptor approach (Christensen, McDonald, Altman, & Palmer, 2018), in which rapid strong experimentation and repeated failure are used to iterate and quickly identify successful or appealing transformations.

Disruptive technologies rapidly change systems and practices because they have recognizably superior attributes to the technology that they replace. Within archeology this does occur, we would contend, at a relatively small scale, where projects or organizations may be participating in the research and development of some of these technologies. However, more broadly as a discipline the pattern for change of practice linked to new technologies often results in a model of incremental small changes, which seek to
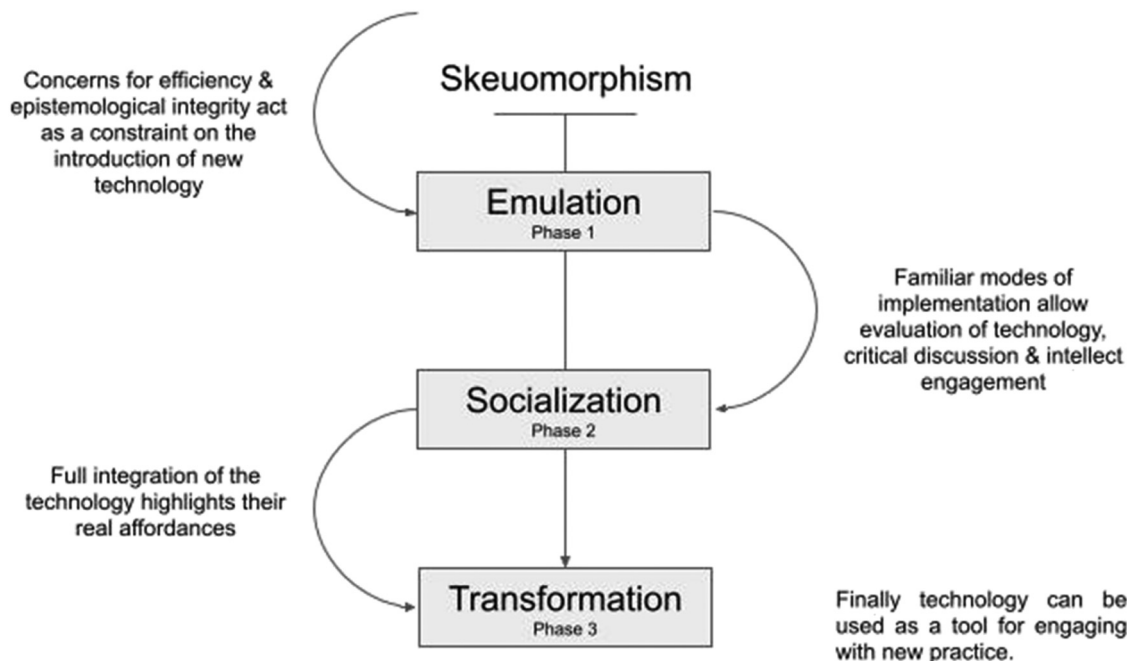
Figure 1: Diagram showing how the process of adopting accepting and integrating new or emergent technology (such as 3D recording and visualization) may move through successive conceptual phases of practice (emulation, socialization, and transformation) by an archeological team, highlighting the importance of "skeuomorphic practice" as described by the authors. The three steps are connected by episodes, which occurred during the process that might equally occur at a disciplinary level.

fit the new technology into existing workflows, practices, and habits, adapting them to accommodate it where needed. This approach tends to place a focus upon the technical specifics and quality of data acquisition and outputs, rather than considering the underlying values, beliefs, and assumptions that would need to accompany any systemic changes in practice that new technologies may afford.

In Section 4, we will review the ways in which this has manifested by examining the way new and emergent digital technologies were adopted within the framework of two vastly different field projects: (1) a long-term project that navigated the shift from analog to digital workflows: Catalhoyuk (Anatolia, Turkey); (2) a "born digital" project: Kämpinge (Scania, Sweden), where 3D recording and visualization techniques were introduced from the outset as a major component of the field practice.

4 Case Study: Çatalhöyük

The Çatalhöyük Research Project studying the Neolithic site of Çatalhöyük in central Anatolia (Turkey) was engaged with the development of and experimentation with various technological approaches consistently throughout its lifespan from its outset. For the most part, this was closely linked to the project's desire to develop its flagship "reflexive" working practice (Farid, 2015; Hodder, 1997, 2000a, 2000b, 2003, 2008). Although the issues with the implementation of this approach have been summarized and reassessed elsewhere (see Berggren & Nilsson, 2014; Berggren et al., 2015; Farid, 2015), it must be borne in mind that for the most part, engagement with digital technologies in the recording and interpretative workflow (i.e., as a tool for knowledge creation) on the project were almost exclusively initiated and developed with this agenda of reflexive practice in mind (Berggren et al., 2015; Taylor et al., 2018). The one possible exception to this being the initial adoption of the project's central relational MS-SQL database (constructed with a Microsoft Access database front end). However, even the project's DBMS was not conventional from a

design perspective essentially consisting of an amalgam of a central excavation database and several satellite specialist databases, which were combined as a single database management system (DBMS) in 2004 (Lukas, Engel, & Mazzucato, 2018).

From this point onward, the DBMS formed the core of the Çatalhöyük Research Project's digital infrastructure. However, the underlying reflexive agenda of the project can be seen in the fractured conception of the DBMS for the first 10 years of its life and the even longer flexibility in data entry, which was initially deliberately conceived to facilitate multivocality (multiple datasets, multiple team voices, and multiple interpretations of the archeology). As such the development of this database was not uniform and to some extent represents an example of bad practice in terms of database design, and it was conceived that *ad hoc* and various systems were amalgamated into one large system based on the evolving requirements of the project; as such the system was never formally planned at the outset based on user needs and fully normalized in line with best practice for database design and implementation (Jones, 2012; Ridge & Jones, 2006; Ridge & May, 2004; Ridge, May, & Mackie, 2005; and see also Lukas et al., 2018).

With the DBMS situated on local servers acting as a digital hub, the project was quick to experiment with a range of other established and emergent digital technologies throughout its lifespan (as discussed later) including geographic information systems (GIS) and 3D data acquisition techniques and tablet technologies; as well as virtual reality (VR) modeling, digital survey, photography, videography, sketching, and so on (for an overview of this engagement with digital technology and media, see Berggren et al., 2015). Throughout the process of adopting and engaging with digital technologies, the project continued to wrestle with a tension between its fluid and reflexive approach to recording and multivocality, and the constraints of the data structures of the digital technologies it sought to experiment with (see Lukas et al., 2018 for a more detailed discussion of these tensions) (Figure 2).

Figure 2: A site in transition – reflexive (?) discussion over analogue records at Çatalhöyük's "trowel's edge," with the aide of tablet access to the project's integrated DBMS and GIS, sat amidst the accouterments of analog practice (image from Taylor et al., 2018 and by Jason Quinlan, courtesy of the Çatalhöyük Research Project; CC BY-NC 4.0).

In 2009, the design and implementation of an intrasite GIS (ibid.) and its integration into the digital infrastructure for the project in subsequent seasons meant that the "digital" capacity of the project increased exponentially. This provided the means to realize a nascent plan to develop the digital recording workflows of the project in 2013 and finally make the project paperless in 2017 (Taylor et al., 2018). The move to paperless was turbo-charged on the project by the introduction of, and experimentation with, two key digital technologies/hardware: 3D data acquisition (including laser scanners, but especially the increasingly affordable/accessible computer vision or structure from motion acquisition techniques) and touchscreen tablet technologies (Berggren et al., 2015; Forte et al., 2012; Forte, Dell'Unto, Jonsson, & Lercari, 2015; Taylor et al., 2018). Under the remit of the 3(D)igging project (Forte et al., 2012), the team initially aimed to evaluate the potential of these 3D technologies within the excavation process, as tools both for recording on-site and for the visualization of the archeological material. The ultimate goal was to be able to input all graphical data (which would otherwise be hand drawn) into the GIS and be able to access, view, and edit these data in the field with the hope of exploring the potential of tablets for integration with other types of digital recording (photography, Harris Matrices, 3D Models, etc.). However, it was specifically the potential affordances of combining 3D data with the GIS on tablets, *in the field, at the trowel's edge*, for facilitating a new reflexive interpretative approach to digital recording in the field (in line with the projects *raison d'etre*), which really resulted in the formalized development of workflows for 3D-GIS recording (Taylor et al., 2018). Although the full paperless (and "reflexive") recording was hindered initially by the absence of reliable wireless network coverage across excavation areas until the 2017 season, installation of which finally allowed full data entry directly into the integrated DBMS/GIS.

So, together with the DBMS, intrasite GIS, and 3D tablet-based on-site recording formed a core suite of technologies that underpinned the final digital recording workflows of the Çatalhöyük Research Project; these core technologies can be essentially seen as arriving in two "waves," detailed in Figure 3. This kind of engagement can be seen in digital workflows on other projects operating over the same time period (see, for example, Opitz, 2015; Opitz & Johnson, 2016; Poehler & Ellis, 2012; Roosevelt, Cobb, Moss, Olson, & Ünlüsoy, 2015, to name but a few high profile examples).
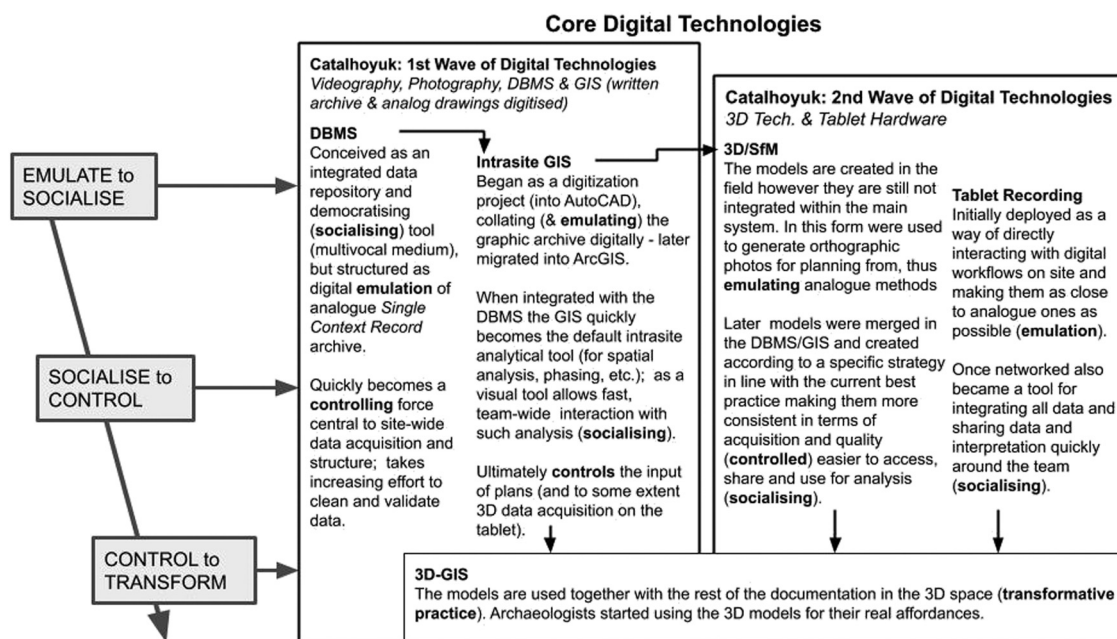

Figure 3: Diagram showing how the core digital technologies, which comprised the digital infrastructure at the Çatalhöyük Research Project, ultimately fit into the schema outlined in Figure 1.

4.1 Çatalhöyük's 1st Wave of Digital Infrastructure

The first wave commenced and developed from 1993 onward (at Çatalhöyük at least) and utilized mature technologies (relational databases and GIS), whilst the second wave from around 2013 made use of emergent technologies (3D technologies and tablets). If we insert these technologies into the framework of the development of practice outlined in Figure 3, then a picture emerges of a pattern of skeuomorphic practice in the adoption of these technologies before they become truly transformative.

In the first wave, the DBMS and GIS were specifically designed to digitize and capture extant analog data. As such, as far as possible, database forms *emulated* their analog counterparts (the single context field recording form, which underpinned all the onsite recording). Similarly, the digitized data are entered into the GIS, as is commonly the case initially formed a digital "*simulacrum*" (*emulation*) of the analog graphical archive (originally on permatrace; Figure 4), minus many of the useful interpretive aspects of its original form (i.e., annotation, hachures, or lines of truncation or uncertainty). In this sense, the digital product was not only another type of digital skeuomorph *but also a* duplication of an extant physical archive — albeit with computational analytical capacity.

In fact, within the framework proposed earlier, it is the novel analytical affordances of these digital approaches that effectively *socialize* the technology to the team after it was introduced. As team members not only get used to entering data within the *emulated* digital framework but also rapidly see that you can "do more things with it" analytically or visualize that data in interesting ways.

Once the digital DBMS/GIS was accepted by the team (fully *socialized*), then it did not take long to crystallize digitally. The requirement of getting data into the new digital infrastructure accurately in a way that it can be effectively queried and serve the needs of the whole team means that the data collection onsite required new levels of quality control. There was a requirement for stronger consistency in the primary written and graphic archive and a huge amount of digital data validation, which to some extent took the project by surprise. In the early years (pre-GIS), when the graphic archive was exclusively utilized in its
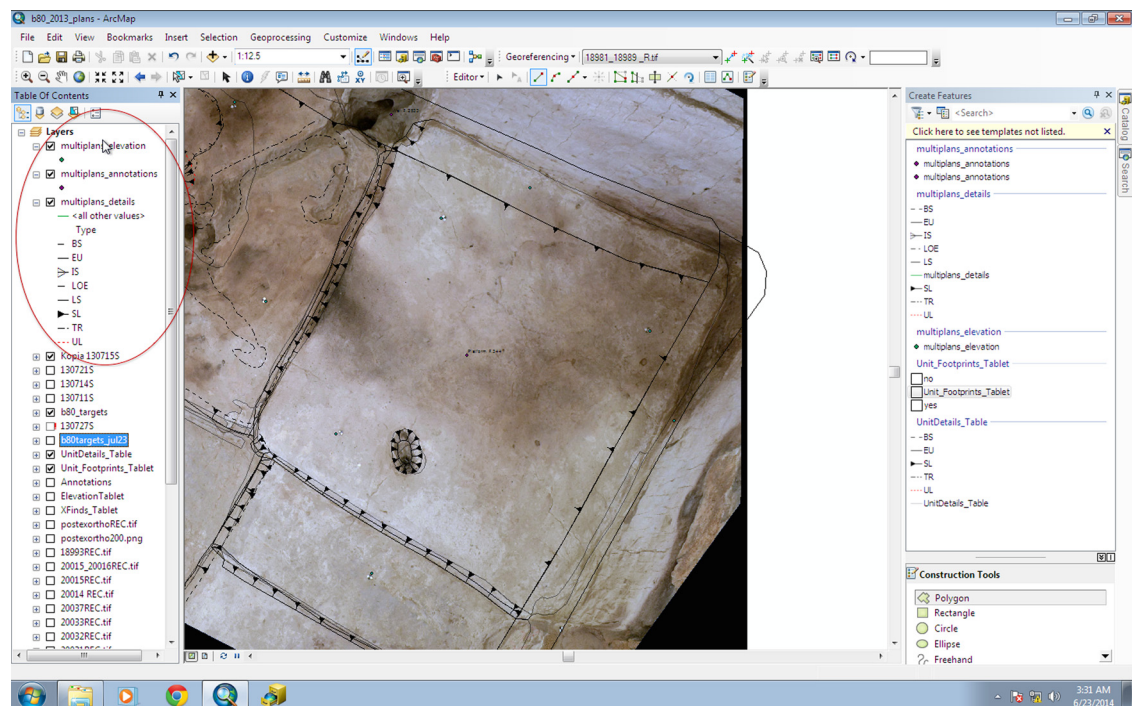

Figure 4: An example of a "digital simulacrum" from Çatalhöyük; a "flattened" 2D orthophoto is exported from a 3D model, georectified, and imported into the project intrasite GIS for planning as part of a paperless system (note the emulation of "Museum of London Archaeology Service-style" planning conventions in the GIS symbology) (from Taylor & Issavi, 2014).

analog form to construct Harris Matrices and build local and site-wide phasing that was then incorporated into the database, there was a huge amount of scope for variation of practice (of recording, of degrees of interpretation in the primary record, even of postexcavation grouping and phasing practice). Once the integrated DBMS/GIS was rolled out, then the experiences of the team in validating the digitized data sets of the early years meant that as the integrated digital infrastructure was accepted by the team as a core mode of analysis (i.e., fully *socialized* by the team), the project had an interest in making sure that any new data created by team members "fit" into the infrastructure and were validated (as far as possible) at the point of creation (*controlled*).

4.2 Çatalhöyük's Second Wave of Digital Infrastructure

It is within the context of the crystallization of the Çatalhöyük Research Project's first wave of digital infrastructure as a *controlling* force for the generation of data (which was essentially a digital skeuomorph of the underlying analog recording system) that the second wave of digital technologies was introduced to the project, from around 2013. With hindsight, and with reference to the framework in Figure 1, this was the *transformative* moment of the first wave, since, as noted earlier, the second wave began with an air of experimentation and desire to innovate using 3D data acquisition techniques and tablet technologies in the field. However, the desire to find a way to integrate these technologies into the extant data infrastructure and interpretative process (so that it complemented and fit within the preexisting data structure) of the project was a primary goal from the outset. In essence, the adoption of new technologies was only deemed acceptable if it could be shown to work within the extant data framework and had to emulate the existing system. With the first wave technologies now *socially* accepted, the already *emulatory* technologies of the first wave immediately had a *controlling* influence over the newly introduced second wave technologies.

As such, the 3D/Tablet recording workflow developed by the project (Taylor et al., 2018) was by default and with little contest conceived as a *skeuomorphic emulation* of existing recording processes, effectively digitalizing the last remaining analog part of the recording process (the onsite drawing and form filling). In this sense, the first wave technologies can be seen as having a direct *controlling* effect on the introduction of the second wave. The on-site 3D workflow was deliberately designed to emulate the analog recording process as far as possible, partly to make new data types "fit" into the projects existing digital infrastructure and partly so as to preserve, as far as possible, the reflexive process "at the trowel's edge," which is inherent in the original analog workflow (i.e., the annotation, the amendment of drawings, the uncertain edges, and interpretations) (Berggren et al., 2015; Taylor et al., 2018). 3D models were used to produce orthophotos, which could be imported and rectified in the GIS to digitize from and annotate. The affordances of the 3D technologies were therefore constrained (or *controlled*) by the extant digital infrastructure.

As the team became familiar with the 3D/Tablet workflow (*socialized*) and became used to working with these second wave technologies, the project as a whole was able to develop a more experimental approach to their use in recording, secure in the knowledge that the technologies they were deploying in an ever increasing shift towards the digital were not compromising the integrity of the project's dataset. This opened a channel for more *transformative* experimentation with 3D annotation (Berggren et al., 2015; Taylor et al., 2018), virtual environments (Lercari, Shiferaw, Forte, & Kopper, 2018), and especially 3D-GIS (Dell'Unto, 2016, 2018). A specific decision was made to systematically record every archeological feature, space, and building retrieved during the investigation; modeling was not therefore attempted systematically at the level of the stratigraphic unit (as, given the processing time and data capacity implications this would have been too granular to manage). However, even this provided ample and sufficient material to start using these new datasets for supporting new practice. After a long phase of socialization with the 3D models, archeologists finally started engaging more and more with these data to gain a diachronic and broad overview of the investigation. The possibility of accessing a rich archive of 3D data triggered an interesting experimentation phase, which (in a few cases) allowed the identification of new archeological information (Knüsel, Haddow, Sadvari, Dell'Unto, & Forte, 2013; Lingle et al., 2015). The 3D GIS made it

possible to easily merge and visualize structures and features investigated across different seasons. These rich spatial representations were employed for simulating the stratigraphic relations among different groups of buildings and were used for visualizing the combined work of different specialists.

5 Case Study: Kämpinge

After the experience of the Çatalhöyük research project, we developed several experiments for testing the impact of 3D models and 3D GIS in support of archeological practice (Dell'Unto, 2016; Landeschi, Nilsson, & Dell'Unto, 2016). Among different tests conducted within the frame of multiple field projects, the experiments developed at the archeological sites of Kämpinge, Sweden represents a significant example of the transformation of practice.

The archeological site of Kämpinge is located in the southwestern of Sweden, and it belongs to a larger group of Middle and Late Neolithic coastal sites located in the Öresund region dating from 8500 to 6000 cal BP (Brinch Petersen, 2015). During the nineteenth and eighteenth centuries, the area surrounding Kämpinge was subjected to ground-turning activities for increasing agricultural productivity (Torstensdotter Åhlin & Söderberg, 1994), leading to the assumption of the complete loss of the Mesolithic cultural layers. One of the principal goals of the Kämpinge project was investigating the presence of preserved prehistoric cultural layers, and the use of 3D recording and visualization techniques was employed from the very beginning for gaining a spatial visualization of all the archeological piece of evidence retrieved during the different excavation campaigns (Dell'Unto, Landeschi, Apel, & Poggi, 2017).

Despite the previous experience gained at Çatalhöyük, the definition of a new field practice based entirely on 3D recording and visualization technology was not an easy step. Although these new instruments and techniques were introduced in the project at a very early stage at Kämpinge, signs of new practice at this site were visible only after years of *socialization* by the team with these new methods, and despite technically being born digital, a skeuomorphic process was still a necessary condition for reaching a *transformation* of our practice on the Kämpinge project also. This approach was defined after collecting the feedback of different team members across different stages of the investigation (over different seasons), and a real change was noticed only when it was possible to integrate the new datasets at the trowel's edge.

The investigation was conducted between 2014 and 2017 (four excavation seasons) by a team of students and teachers from the Department of Archaeology and Ancient History at Lund University. Since the first campaign, 3D spatial recording technologies were employed in the field as the main media for supporting operations of documentation and mapping. During that first season (2014), tablet computers were *not* sufficiently powerful for computing and visualizing 3D models. Hence, 3D data were processed and implemented in a 3D GIS during postexcavation activities (Dell'Unto et al., 2017). From 2015, due mainly to rapid advances in hardware, it was possible to process, integrate, and use the 3D models in the field. This represented an important step in the process. The methodology designed for producing the archeological documentation was based on the combination of RTK Global Positioning System with differential correction and image-based 3D modeling (IBM).

Once established, the technology used in the field at Kämpinge did not undergo substantial changes over the years; however, considerable shifts in practice occurred across different seasons, where the use of the instruments in the field (RTK GPS, IBM, and 3D GIS) was further adapted to support new practice and 3D visualization technology (Tablets and 3D GIS) was increasingly used in the trench to support discussion among the different team members working on site. Before being able to fully engage with these methods, it was necessary to socialize with these new instruments (and data) through a process of *emulation*, where instruments and 3D models produced during the investigation process were constantly evaluated against more traditional graphic datasets. During the first season, the RTK GPS was used for recording control points, for documenting the position of artifacts, and for drawing contexts and features retrieved during the investigation. The 3D polylines generated as a result of this process were later imported into the 3D GIS and

superimposed into the 3D Models (Figure 5). The use of Total Station or RTK GPS for producing the graphic documentation is a common and well-established practice in Sweden, and despite the possibilities offered by this new methodology (RTK GPS + IBM), we ended up producing data in a very similar way. The aim was to socialize the technology through a process of emulation (as a digital skeuomorph of practice).

The possibility of storing and combining 3D polylines with 3D surface models was of course an important development; however, the impossibility of using the system in the field considerably diminished its impact during the interpretation process. The results of this first test highlighted two important aspects: (1) the 3D surface models were not significantly affecting our interpretation process and (2) to understand the real potential of these datasets, it was necessary to start engaging with them in the field. A critical evaluation of this first experimentation induced a process of *socialization*, which allowed the identification of the steps necessary for testing new field practices.

During the second season, we were able to start testing tablet PCs for generating, managing, and visualizing 3D models directly in the field. This time the use of the RTK GPS was limited to record ground control points for georeferencing the 3D models. Once implemented into the geodatabase, the 3D models were used by the archeologist at the trowel's edge for drawing contexts and features directly in the 3D space GIS (Figure 6) and for reviewing documentation from the previous season. The possibility of accessing all the records through the tablet PC in the field encouraged the discussion among archeologists and had a significant impact on the excavation strategy. At the beginning of this experimentation, we did not explicitly consider these scenarios, which (in terms of field practice) turned out to be the most significant part of the field project.

In the last two excavation campaigns (2016–2017), archeologists started using the system more and more for assessing hypotheses and for tracking connections between contexts and/or artifacts identified across different seasons. This long and dynamic process of socialization led to a significant *transformation* of the field practice, where digital recording and visualization tools have had a changing function and meaning.
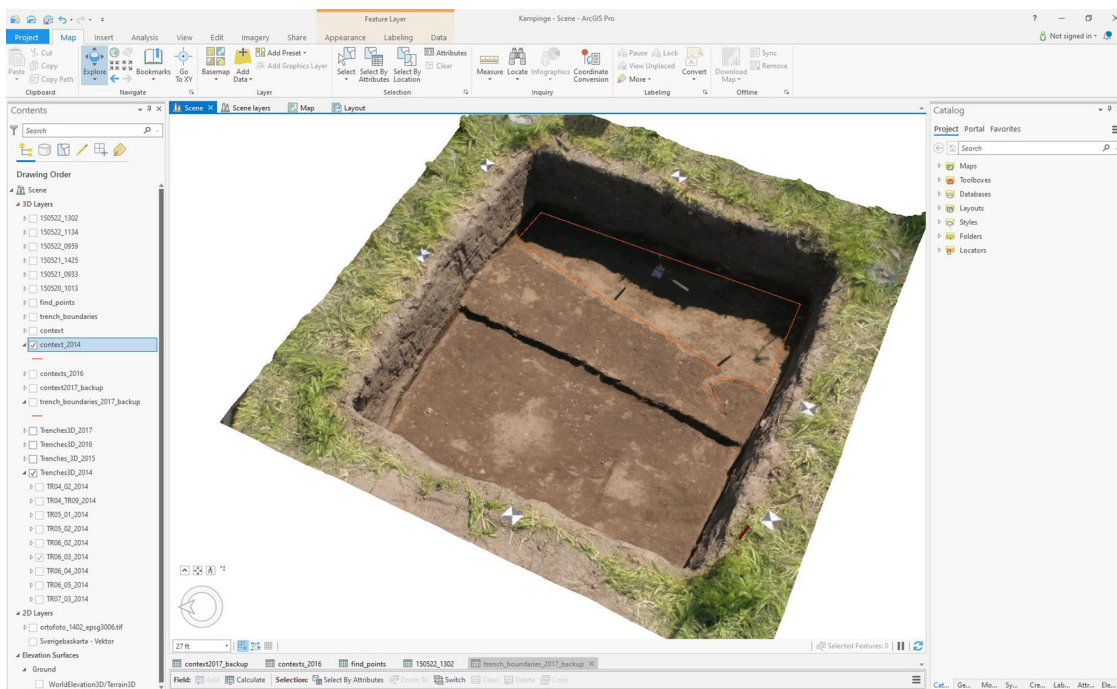

Figure 5: 3D models of trench 6 excavated during the excavation campaign 2014. The model was implemented in the 3D GIS during postexcavation activities. The shapefiles (in orange) were created using RTK differential GPS and superimposed directly on the model. The polylines created with the RTK GPS do not allow a proper geometrical description of complex shapes and cannot be verified in the field.
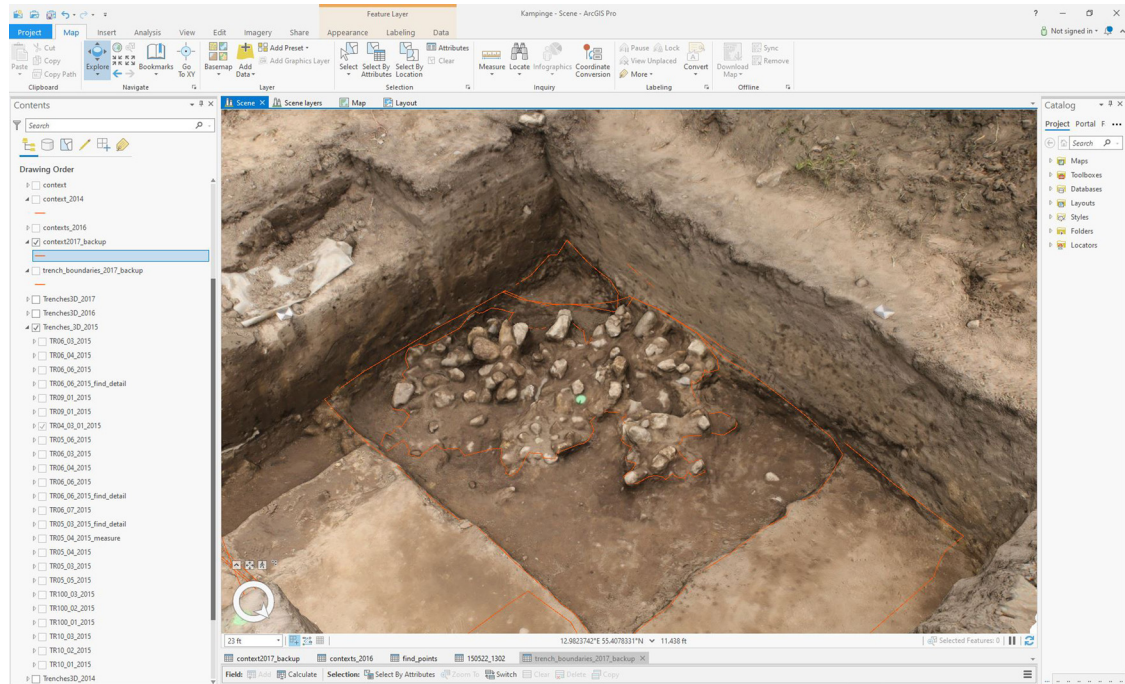
Figure 6: 3D models of trench 9 excavated during the excavation campaign 2016. The model was generated and implemented into the 3D GIS during the excavation. The model was visualized in the field using a Tablet computer and was used as geometrical reference for drawing the contexts. This method allowed verifying the quality of the graphic representation against the real contexts/features.

6 Concluding Discussion

The skeuomorphic practice and data structures identified at the sites mentioned earlier formed a critical part of a process of digital socialization and control, which ultimately fed into a transformation of practice for the two projects involved. We see this transformative process as being analogous with disciplinary trends, and it is worth noting that a wider tendency toward skeuomorphism in digital practice has been discussed elsewhere (Morgan, 2019). This process is absolutely critical if new and emergent cutting- or "bleeding-edge" technologies are to be accepted as the standard into our digital practice (not only on a project-by-project basis but also at a disciplinary level). The performance and practice benchmarking, which is characterized by the long socialization of these technologies began as an internal process (i.e., project specific as projects/organizations/individuals adopt and experiment with new technologies), but over a longer period do contribute to wider change as more organizations and projects adopt the technologies (increasing capacity for external benchmarking by comparing metrics and/or practices across these organizations and projects); again this relies upon wider acceptance and socialization of the technology at a disciplinary level. The ultimate transformations of practice that we refer to here could be simple as a "para-perceptive" shift (after Buccellati, 2017, see above) from analog to digital, or from digital to "new-digital," but either way it will have a tangible effect on the way knowledge is produced in these archeological investigations.

To illustrate the idea of "para-perception," Buccellatti draws a powerful analogy between the "Digital Turn" and the development of writing (perhaps the most significant leap in the "creation" and "convey-ance" of knowledge, in the whole history of western science, and, arguably, the development of Humankind). He sees profound parallels in the shift from "*verbal*" to "*literate* thought," embodied in a series of successive steps through logical thought and language, in which "para-perception" of the struc-ture of language (ultimately embodied by writing) is achieved, culminating in writing itself (a new and

ubiquitous communication technology). Writing, he argues, emerged through a need to "brace the discontiguity" of the underlying *verbal logical thought* and *language as a related but separate entity*, in the same way that a distinct mode of *digital thought* is currently emerging (both in Archeology as a discipline and in society generally) as the mechanism for bridging the gap between increasingly ubiquitous *discontiguous*, often atomized digital objects (data?) and the need to reassemble these into some sort of sequence or narrative, an act he calls "*digital bracing*" (ibid., p. 173).

In particular, the notion of *para-perception*, or more specifically within the context of the "Digital Turn" in Archeology what Buccellati calls "*para-digital*," is useful again in framing the notion of *skueomorphic digital practice*. The *para-digital* here is the transformative (and near constant) everyday engagement with digital stimuli specifically (i.e., websites, hyperlinks, games) by society, without explicitly articulating or considering their theoretical importance (ibid., p. 197). At a disciplinary level, it could be argued that the tendency to emulate analog practice, particularly in the formative development of digital tools in our digital practice (such as we saw Çatalhöyük and Kämpinge) actually forms part of the process of our developing a "para-perception" of our new digital technologies; our very own *para-digital*; or coming to terms as practitioners with the performance of the digital as part of the transformation toward true "digital thinking."

Related to this perhaps, Edgeworth (2015, p. 5) notes that the "digitalization" of archeology (the "Digital Turn?") does *not* just apply to *certain* processes on-site or in our analysis of databases. He points out that the digitalization of the discipline is a much more holistic thing, encompassing project administration and communications, acquisition of raw data (such as baseline data and maps, which are often mostly digital), and our filing protocols for project outputs – all drawing on a raft of specialized software (and hardware):

> Now, in the more developed digital age, the use and influence of computers is so widespread that it is not quite so clear exactly where the main site of archaeological discovery is located in space. New forms of discovery have arisen on-screen in addition to those that have always taken place out on-site. Indeed, the term "site of discovery" might usefully be taken to refer to virtual on-screen realities as well as off-screen ones (2015, p. 4).

At a disciplinary level then, perhaps the para-digital is already happening? Since the (*para-*)digitalization of the discipline increasingly encompasses *all* aspects of our practice, our knowledge creation, and dissemination, we would suggest that the emulatory skeuomorphism of digital practice and data structure that we saw at Çatalhöyük and Kämpinge are not only completely normal but also essential to the process of socializing new technologies within project (and ultimately disciplinary) infrastructure, as a means to control them until such time as the whole team (or discipline) is comfortable enough with their affordances and operation (i.e., becomes para-digital) that they can have a truly transformative effect on practice.

If we think again about the broader models of incremental versus systemic organizational change that digital technologies may afford the discipline, we would argue that tendency of archeology toward both *technological skueomorphs* and *skeuomorphs of practice* is to some extent rooted in a resistance to completely rethinking workflows, practices, and habits which would necessarily set in motion large (probably painful in the short-term), experimental changes to fully take advantage of the benefits of the new technology. Indeed, perhaps a longer process of socialization of new technologies and smaller incremental change is not only more desirable but also arguably more appropriate in situations where there is a perceived duty of care (in this case, the ethical duty of archeological practitioners to preserve the archeological record; the potential for catastrophic failure of a technology is a risk that many practitioners are wary of in the "unrepeatable experiment" of archeological excavation).

Having said this one of the interesting things to come out of our own (the author's) experiences of developing the digital field recording on these and other sites (not discussed here) is the diversity of engagement and general overall *support* for this change in practice. Certainly, at Çatalhöyük, for example, various stakeholders within the project environment fell into specific "camps," with specific visions of what digital practice should look like in the field. There was a relationship between the structure of the project and its social hierarchies, with the team members introducing these technological changes initially coming into an established project infrastructure with its own tradition of recording. So, the team thinking here, perhaps unsurprisingly, spanned a diverse spectrum of ideal practice, ranging from the conservative (highly skeuomorphic ideal of digital practice) to the progressive (highly transformative ideal of digital

practice). Discussion of the best ways to implement new technologies at Çatalhöyük in particular could be passionate, and concessions on both sides were hard-won. Again, this is analogous to the wider disciplinary discussion about what is "best-practice" (see Forte et al., 2012; Galeazzi, 2016; Galeazzi & Di Giuseppantonio Di Franco, 2017; or Opitz & Limp, 2015). However, in reality, it becomes evident with the benefit of hindsight that, despite an impassioned defense of each of our particular visions of digital practice, we were all working within the same process. Ultimately the discussion was never really about the different fractured ideas about how emergent technology *should be used*, but rather about how to reach a socialized and controlled consensus about the technologies implementation and an acceptable transformation of our wider digital practice as a project.

Ultimately we would concur with scholars like Huggett (2017), Caraher (2016), and Morgan (2019) who emphasize the importance of reflexive, creative, nonnormative, and experimental digital practice in Archeology. However, we would also suggest that a certain conservative and normative skeuomorphism of practice (i.e., the mimetic emulation of earlier methodological approaches in the implementation of new digital technologies) should not be viewed as a negative, but rather, perhaps, as the key to socializing these technologies and exploring their potential and limitations in order that we can really ascertain what we can do with the make them understandable to a wider user base. To embrace new and emergent technologies, it is important that all the stakeholders in a project (in the discipline?) are satisfied that nothing of the earlier modes of knowledge creation is lost. This may or may not be a problem, perhaps some of the "old ways" are legitimately inferior, or no longer "fit for purpose," but each change needs to be negotiated on its own terms. Technology needs to be tested (*can it be shown to do what we do already as a baseline?*) and challenged (*pushed "till it breaks?"*) through implementation and reflexively critiqued in such a way that the epistemological framework of the project remains intact, albeit augmented, *despite* the new effects of the new technology on digital practice. Once a new technology is perceived as being both controllable and socialized (read: accepted, or even "para-digital"), then there is genuine scope to transform our practice.

References

Berggren, Å., & Nilsson, B. (2014). Going back, looking forward: Reflexive archaeology or reflexive method? In I. Hodder (Ed.), *Integrating Çatalhöyük. Themes from the 2000–2008 seasons* (Vol. 10, pp. 57–70). Los Angeles: Cotsen Institute of Archaeology Press.

Berggren, Å, Dell'Unto, N., Forte, M., Haddow, S., Hodder, I., Issavi, J., … Taylor, J. (2015). Revisiting reflexive archaeology at Çatalhöyük: Integrating digital and 3D technologies at the trowel's edge. *Antiquity*, *89*(344), 433–448. doi: 10.15184/aqy.2014.43.

Bonelli, L. (2016). From skeuomorphism to material design and back. The language of colours in the 2nd generation of mobile interface design. In D. Gadia (Ed.), *Colour and colorimetry. Mutidisciplinary contributions* (Vol. XII B). Torin: Gruppo del Colore.

Brinch Petersen, E. (2015). Diversity of Mesolithic Vedbaek. *Acta Archaeologica*, *86*(1), 7–13.

Buccellati, G. (2017). *A critique of archaeological reason: Structural, digital, and philosophical aspects of the excavated record*. Cambridge: Cambridge University Press. doi: 10.1017/9781107110298.

Callieri, M., Dell'Unto, N., Dellepiane, M., Scopigno, R., Soderberg, B., & Larsson, L. (2011). Documentation and interpretation of an archeological excavation: An experience with dense stereo reconstruction tools. In M. Dellepiane, F. Nicolucci, S. P. Serna, H. Rushmeier, & L. Van Gool (Eds.), *VAST 2011 – The 12th international symposium on virtual reality, archaeology and cultural heritage* (Prato, 18–21 October 2011, pp. 33–40). Geneve: Eurographics Association.

Campiani, A., Lingle, A., & Lercari, N. (2019). Spatial analysis and heritage conservation leveraging 3-D data and GIS for monitoring earthen architecture. *Journal of Cultural Heritage*, *39*, 166–176. doi: 10.1016/j.culher.2019.02.011.

Caraher, W. (2015). Slow Archaeology. *North Dakota Quarterly*, *80*(2), 43–52.

Caraher, W. (2016). Slow archaeology: technology, efficiency, and archaeological work. In E. W. Averett, D. Counts, & J. Gordon (Eds.), *Mobilizing the past: Recent approaches to archaeological fieldwork in a digital age* (pp. 421–441). Grand Forks: The Digital Press at The University of North Dakota.

Christensen, C. M., McDonald, R., Altman, E. J., & Palmer, J. E. (2018). Disruptive innovation: An intellectual history and directions for future research. *Journal of Management Studies*, *55*, 1043–1078. doi: 10.1111/joms.12349.

Costopoulos, A. (2016). Digital archaeology is here (and has been for a while). *Frontiers in Digital Humanities*, *3*(4), 1–3 doi: 10.3389/fdigh.2016.00004.

Dellepiane, M., Dell'Unto, N., Callieri, M., Lindgren, S., & Scopigno, R. (2013). Archeological excavation monitoring using dense stereo matching techniques. *Journal of Cultural Heritage*, *14*(3), 201–210.

Dell'Unto, N. (2016). Using 3D GIS platforms to analyse and interpret the past. In M. Forte & S. Campana (Eds.), *Digital methods and remote sensing in archaeology: Archaeology in the age of sensing* (pp. 305–322). Cham, Switzerland: Springer.

Dell'Unto, N. (2018). 3D models and knowledge production. In I. Huvila (Ed.), *Archaeology and archaeological information in the digital society* (pp. 54–69). Oxon, UK: Routledge.

Dell'Unto, N., Landeschi, G., Apel, J., & Poggi, G. (2017). 4D recording at the Trowel's edge: Using three-dimensional simulation platforms to support field interpretation. *Journal of Archaeological Science: Reports*, *12*, 632–645. doi: 10.1016/j.jasrep.2017.03.011.

De Reu, J., Trachet, J., Laloo, P., & De Clercq, W. (2016). From low cost UAV survey to high resolution topographic data: Developing our understanding of a medieval outport of bruges. *Archaeological Prospection*, *23*(4), 335–346. doi: 10.1002/arp.1547.

Doneus, M., Verhoeven, G., Fera, M., Briese, C., Kucera, C., & Neubauer, W. (2011). From deposit to point cloud. A study of low-cost computer vision approaches for the straightforward documentation of archaeological excavation. *XXIII International CIPA Symposium Geomatics*, *6*, 81–88.

Edgeworth, M. (2015). From spade-work to screen-work: New forms of archaeological discovery in digital space. In M. Carusi, A. S. Hoel, T. Webmoor & S. Woolgar (Eds.), *Visualisation in the age of computerization* (pp. 40–58). London: Routledge Studies in Science, Technology and Society.

Farid, S. (2015). Proportional representations. Multiple voices in archaeological interpretation at Çatalhöyük. In R. Chapman & A. Wylie (Eds.), *Material evidence. Learning from archaeological practice* (pp. 59–78). London and New York: Routledge.

Forte, M., Dell'Unto, N., Issavi, J., Onsurez, L., & Lercari, N. (2012). 3D archaeology at Çatalhöyük. *International Journal of Heritage in The Digital Era*, *1*(3), 351–378. doi: 10.1260/2047-4970.1.3.351.

Forte, M., Dell'Unto, N., Jonsson, K., & Lercari, N. (2015). Interpretation process at Çatalhöyük using 3D. In I. Hodder & A. Marciniak (Eds.), *Themes in contemporary archaeology: Assembling Çatalhöyük*. Leeds: Maney Publishing.

Frieman, C. J. (2013). Innovation and identity: The language and reality of prehistoric imitation and technological change. In Jeb J. Card (Ed.), *Hybrid material culture: The archaeology of syncretism and ethnogenesis* (pp. 318–341). Carbondale, IL: Center for Archaeological Investigations.

Galeazzi, F. (2016). Towards the definition of best 3D practices in archaeology: Assessing 3D documentation techniques for intra-site data recording. *Journal of Cultural Heritage*, *17*, 159–169. doi: 10.1016/j.culher.2015.07.005.

Galeazzi, F., & Di Giuseppantonio Di Franco, P. (2017). Theorising 3D visualisation systems in archaeology: Towards more effective design, evaluations and life cycles. *Internet Archaeology*, *44*. doi: 10.11141/ia.44.5.

Gölzer, P., & Fritzsche, A. (2017). Data-driven operations management: Organisational implications of the digital transformation in industrial practice. *Production Planning and Control*, *28*(16), 1332–1343. doi: 10.1080/09537287.2017.1375148.

Gošić, M. (2015). Skeuomorphism, boundary objects and socialization of the Chalcolithic metallurgy in the southern Levant. *Issues in Ethnology and Anthropology*, *10*, 717–740. doi: 10.21301/eap.v10i3.8.

Hodder, I. (1997). 'Always momentary, fluid and flexible': Towards a reflexive excavation methodology. *Antiquity*, *71*(273), 691–700. doi: 10.1017/S0003598X00085410.

Hodder, I. (2000a). Developing a reflexive method in archaeology. In I. Hodder (Ed.), *Towards reflexive method in archaeology: The example of Çatalhöyük* (British Institute at Ankara & MacDonald Institute for Archaeological Research) (pp. 3–14). Oxford: Oxbow Books.

Hodder, I. (2000b). Where is Çatalhöyük? Developing a reflexive method in archaeology. In I. Hodder (Ed.), *Towards reflexive method in archaeology: The example at Çatalhöyük* (pp. 3–15). Cambridge: McDonald Institute for Archaeological Research, University of Cambridge.

Hodder, I. (2003). Archaeological Reflexivity and the "Local" voice. *Anthropological Quarterly*, *76*(1), 55–69. doi: 10.1353/anq.2003.0010.

Hodder, I. (2008). Multivocality and social archaeology. In J. Habu, C. Fawcett, & J. M. Matsunaga (Eds.), *Evaluating multiple narratives. Beyond nationalist, colonialist, imperialist archaeologies* (pp. 196–200). New York, NY: Springer.

Hopkinson, G., & Winters, J. (2003). Problems with Permatrace: A note on digital image publication. *Internet Archaeology*, *14*. doi: 10.11141/ia.14.5.

Huggett, J. (2017). The apparatus of digital archaeology. *Internet Archaeology*, *44*. doi: 10.11141/ia.44.7.

Jones, S. (2012). *The Çatalhöyük database system*. Unpublished Internal Report.

Knappett, C. (2002). Photographs, skeuomorphs and marionettes. Some thoughts on mind, agency and object. *Journal of Material Culture*, *7*(1), 97–117.

Knüsel, C. J., Haddow, S. D., Sadvari, J. D., Dell'Unto, N., & Forte, M. (9–13 April 2013). Bioarchaeology in 3D: Three-dimensional modeling of human burials at Neolithic Çatalhöyük. *Poster presented at 82nd meeting of the American Association of Physical Anthropologists*. Knoxville, TN. doi: 10.13140/RG.2.2.18447.69287.

Landeschi, G., Nilsson, B., & Dell'Unto, N. (2016). Assessing the damage of an archaeological site: New contributions from the combination of Image-based 3D modelling techniques and GIS. *Journal of Archaeological Science: Reports*, *10*, 431–440.

Lercari, N., Shiferaw, E., Forte, M., & Kopper, R. (2018). Immersive visualization and curation of archaeological heritage data Catalhoyuk and the dig@ IT app. *Journal of Archaeological Method and Theory*, *25*(2), 368–392.

Lerma, J. L., Navarro, S., Cabrelles, M., & Villaverde, V. (2010). Terrestrial laser scanning and close range photogrammetry for 3D archaeological documentation: The Upper Palaeolithic Cave of Parpallo as a case study. *Journal of Archaeological Science*, *37*, 499–507.

Lingle, A., Dell'Unto, N., Der, L., Doyle, S., Killackey, K., Klimowicz, A., … Tung, B. (2015). *Painted plaster head* (Çatalhöyük 2015 Archive Report, report by the Çatalhöyük Research Project 44–8). Retrieved from Catalhoyuk Research Project website: http://www.catalhoyuk.com/research/archive_reports

Löbbing, J. (2015). The concept of skeuomorphism and the spread of glass vessels in the Augustian period. In *August i les províncies occidentals. 2000 aniversari de la mort d'August: Tarraco Biennal, actes. 2on Congrés Internacional d'Arqueologia i Món Antic Tarragona, 26–29 de noviembre de 2014* (Vol. 1, pp. 105–112). Tarragona: Institut Català d'Arqueologia Clàssica.

Lukas, D., Engel, C., & Mazzucato, C. (2018). Towards a living archive: Making multi layered research data and knowledge generation transparent, *Journal of Field Archaeology*, *43*(1), S19–S30. doi: 10.1080/00934.

McPherron, S. P, Gernat, T., & Hublin, J.-J. (2009). Structured light scanning for high-resolution documentation of in situ archaeological finds. *Journal of Archaeological Science*, *36*, 19–24. doi: 10.1016/j.jas.2008.06.028.

Morgan, C. (2019). Avatars, monsters, and machines: A Cyborg archaeology. *European Journal of Archaeology*, *22*(3), 324–337. doi: 10.1017/eaa.2019.22.

Morgan, C. L., & Wright, H. E. (2018). Pencils and pixels: Drawing and digital media in archaeological field recording. *Journal of Field Archaeology*, *43*(2), 136–151. doi: 10.1080/00934690.2018.1428488.

Opitz, R. (2015). Three dimensional field recording in archaeology: An example from Gabii. In B. R. Olson & W. R. Caraher (Eds.), *Visions of substance: 3D imaging in mediterranean archaeology* (pp. 64–73). Grand Forks, ND: The Digital Press at The University of North Dakota.

Opitz, R., & Johnson, T. D. (2016). Interpretation at the controller's edge: Designing graphical user interfaces for the digital publication of the excavations at Gabii (Italy), *Open Archaeology*, *2015*(1), 274–390. doi: 10.1515/opar-2016-0001.

Opitz, R., & Limp, W. F. (2015). Recent developments in high-density survey and measurement (HDSM) for archaeology: Implications for practice and theory. *Annual Review of Anthropology*, *44*, 347–364. doi: 10.1146/annurev-anthro-102214-013845.

Pavel, C. (2010). *Provenance. Describing and interpreting the past: European and American approaches to the written record of the excavation*. Bucureşti: Editura Universităţii Din Bucureşti, Antiquity Publications Ltd.

Peacock D. (2008). Making ways for change: Museums, disruptive technologies and organisational change. *Museum Management and Curatorship*, *23*(4), 333–351. doi: 10.1080/09647770802517324.

Poehler, E., & Ellis, S. (2012). The 2011 season of the Pompeii Quadriporticus project: The Southern and Northern sides. *Fasti On Line Documents & Research*, *249*, 1–12. http://www.fastionline.org/docs/FOLDER-it-2012-249.pdf

Ridge, M., & May, R. (2004). Database and IT developments [online]. In *Çatalhöyük 2004 archive report*. http://www.catalhoyuk.com/archive_reports/2004/ar04_32.html

Ridge, M., May, R., & Mackie, D. (2005). Çatalhöyük IT team archive report 2005 [online]. In *Çatalhöyük 2005 archive report*. http://www.catalhoyuk.com/sites/default/files/media/pdf/Archive_Report_2005.pdf

Ridge, M., & Jones, S. (2006). IT team [online]. In *Çatalhöyük 2006 archive report*. http://www.catalhoyuk.com/sites/default/files/media/pdf/Archive_Report_2006.pdf

Roosevelt, C. H., Cobb, P., Moss, E., Olson, B. R., & Ünlüsoy, S. (2015). Excavation is destruction digitization: Advances in archaeological practice. *Journal of Field Archaeology*, *40*(3), 325–346. doi: 10.1179/2042458215Y.0000000004.

Star, S. L., & Griesemer, J. R. (1989). Institutional ecology, 'Translations' and boundary objects: Amateurs and professionals in Berkeley's museum of vertebrate zoology, 1907–1939. *Social Studies of Science*, *19*(3), 387–420.

Taylor, T. (1999). Envaluing metal: Theorizing the eneolithic "Hiatus." In S. M. M. Young, A. Mark Pollard, P. Budd, & R. A. Ixer (Eds.), *Metals in antiquity* (BAR International Series 792, pp. 22–32). Oxford: Archaeopress.

Taylor, J. S., & Issavi, J. (2014). *Çatalhöyük research project – tablet recording workflow: Graphics*. Unpublished internal document of the Çatalhöyük Research Project (Updated 25.06.2014).

Taylor, J. S., Issavi, J., Berggren, Å., Lukas, D., Mazzucato, C., Tung, B., & Dell'Unto, N. (2018). 'The Rise of the Machine': The impact of digital tablet recording in the field at Çatalhöyük. *Internet Archaeology*, *47*. doi: 10.11141/ia.47.1.

Torstensdotter Åhlin, I., & Söderberg, B. (1994). *Skåne, Räng socken, Höllviken*, *23*, 7. RAÄ 3, 34 och 39. 1992–1992. Arkeologisk utredning och förundersökning. UV Syd: Riksantikvarieämbetet.

Wilhelmson, H., & Dell'Unto, N. (2015). Virtual taphonomy: A new method integrating excavation and postprocessing in an archaeological context, *American Journal of Physical Anthropology*, *157*(2), 305–321.