Printing the Past: 3D Imaging Technologies and Archaeology

by

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AUTHOR'S DECLARATION:

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

ABSTRACT:

3D Printing and 3D imaging technologies are frequent topics of global discussion. We see countless news media posts and academic articles devoted to what the technology is capable of and how it is currently being used. Some authors focus on how the technology can be implemented into existing archaeological frameworks, whereas others focus on breaking down what the technology is capable of producing at this time. Very few are looking into how this technology and its products are affecting global understandings of objects and material culture. In archaeology, this is particularly relevant for how we see, use, and interpret 3D printed replicas of original artifacts, as well as the original archaeological artifacts themselves. Through a review of current discourse on the subject as well as background anthropological, material culture studies, and archaeological theory, this thesis will explore some of the ways in which archaeology as a discipline needs to begin to think about how using such technology will change our relationships with artifacts, and that indeed it already has. By focusing on one of three potential archaeological sub-foci, research and education, this paper argues the need for archaeologists to consider what 3D imaging will do for the future of archaeological material digitization and questions of information accessibility.

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Dedicated to my mother,

For forever being my inspiration, my mentor, and my hero

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Chapter 1: 3D Printing, Archaeology, and Public Issues Anthropology

Public Issues Anthropology:

The goal of Public Issues Anthropology as implemented in our program is to uncover the public relevance of anthropological approaches and research findings. But how do we determine "public"? There are many "publics," and yet we might also consider a universal "public" interest. Many have tried to piece together a "true" definition of public, and it would seem as though much like many other definitions, it is often relative. Thus, for the purposes of arguing the relevance of my thesis research I will define the "public" of Public Issues Anthropology to be the greater global interest in 3D imaging technologies and their uses. This may include those actively involved academically or out of personal interest, but also those who are merely aware that the technology exists as well as those who might be affected by their products (i.e., university students or museum patrons).

With this definition of "public" in mind, my discussion of 3D imaging technologies and archaeology in chapter two has accurately captured the essence of what our program seeks to accomplish as well as what anthropology as a broader discipline desires to do. Anthropological training encourages the search for covert meanings in the day to day interactions and lived experiences of observed peoples, an element which extends to the study of material culture. The quest for these hidden meanings may be direct, such as in participant observation, or may take place purely in the "public" domain, or those interactions and messages sent into the greater world of human interaction on a global scale. In archaeology, this pursuit can also include a focus on material culture and its messages. It is truly anthropological in spirit then, to take a new technology and its products, analyze our interactions with them, and also incorporate how

new and existing meaning-networks change because of them. I have incorporated anthropological, archaeological, and material culture theory in analyzing 3D imaging technology[1] thus ensuring a balanced anthropological framework with interdisciplinary influences for data analysis.

3D imaging technologies are a commonplace topic in the media at large. Potential sources for the analysis in chapter two are readily available from nearly every conceivable media outlet. Even when not intentionally gathering stories and 3D imaging perspectives, one will frequently come across the term "3D printing" or "3D printed..." used as a buzz-word to draw in attentions of would-be readers, even if the 3D printed adjective is not actually relevant to the story itself[2]. Quite commonly the term, and its technological ties, are used without much description as to the painstaking process behind its use or its products. Like so many other anthropological research topics, it seems clear that 3D printing is being used in the public eye as more than just the new technology at centre stage. There is meaning behind its presence, and most importantly, in its possibilities. Some of the stories focus on negative consequences of the technology[3] whereas other stories, including the majority of archaeologically-specific ones, focus on its benefits, applications, and potentials[4]. These media articles range from large topics about war-torn political climates, to museum applications, art installations, and even local

[1] Ahmed et al. 2014; Benjamin 1999; Berger 2009; Breuckmann et al. 2009; Cameron 2007; Clifford 1993; Dant 2005; Dudley et al. 2011; Fowler 2010; Hahn and Weiss 2013; Hallam 2000; Haraway 1988; Janes 2007; Keesing 2006; Knell et al. 2007; Lonetree 2009; Mann 2003; Martinez and Ames 1997; Olsen 2010; Rapaille 2007; Reisinger and Steiner 2006; Woodward 2007

[2] E.g. Tickle 2015

[3] E.g. Quinto 2015

[4] E.g. Afzal 2013; Alfrod 2015; Allahyari 2015; Aroniwitz 2015; Clark 2013; Flaherty 2012; Griffin 2014; Killgrove 2015; Milward 2015; Neely and Langer 2013; Postrel 2015; Schaffhauser 2015; Smith 2015; Speer 2014; Varin 2013; Zeffler et. al 2015

University of Waterloo student-access[5]. With a topic so prevalent in global fora, as well as the use of "3D printing(/-ed)" as a buzz-word, it would seem that the question of whether or not an analysis of what 3D printed items can do for archaeological artifacts certainly has grounds in the greater public interest.

Museums[6] and archaeologists alike have been utilizing and advocating this technology for some time and with heightened public interest in the subject, my research analysis appears to fall at the nexus of these foci. At once, I am analyzing elements of why the public and archaeologists are so interested in the technology and its products, but I also delve deeper into the understanding of those meanings and connections can do for making archaeological materials more accessible and relatable to the public--layperson and expert alike. The liminal place held by 3D printed items allows for a type of analysis that is at once applicable and relevant both within the discipline as well as for the public at large, while also being reflexive and theoretical in a way that can provide the groundwork towards further study in this direction.

The Publication:

Selecting a single peer-reviewed journal to submit my thesis to in the end was a difficult choice. Due to the topic I chose to explore, a number of publications including anthropological, archaeological, scientific, or technological were all possible outlets. The technological base combined with an archaeological framework initially inclined me towards the Journal of Archaeological Science. However, this did not incorporate the Public Issues component of the

[5] Ramirez 2014

[6] E.g. Waibel 2015

program, and thus the Journal of Archaeological Research, the Journal of Anthropological Archaeology, or Advances in Archaeological Practice: A Journal of the Society for American Archaeology became options. I did not focus on any one particular region of the world for my data collection, and it seemed as though it would be best to choose a publication geared towards the most broadly focused archaeological journal of these selections.

Thus, I ultimately decided the best possible venue would be the American Journal of Archaeology. With a distribution size of over fifty countries and almost one thousand universities, as well as the variety of topics covered by the journal makes its audience the most appropriate choice (AJA 2015). It is an old and successful journal, which signals its openness to new perspectives on where the discipline is headed in light of new technological developments as well as a need for reflexive theoretical analysis about archaeological approaches to those same new technologies. While traditionally they have been a classical archaeology focused journal, I believe this is an asset for my submission. 3D imaging technologies have proven very useful in politically tremulous regions and other circumstances where key archaeological data may be irrevocably lost, particularly in and around sites and materials of classical relevance. Finally, their current incorporation of global archaeological interests, beyond classical antiquities and museum perspectives, is in sync with the kinds of sources and examples I will use within the following chapter.

Chapter 2: Printing the Past: 3D Imaging Technologies and Archaeology

Introduction

The modern world is inundated with technology. It seems as though every year we are moving faster; developing more technologies designed to make our lives "enriched", "entertained", or "easier." Whether in pursuit of making childhood sci-fi fantasies a reality or trying to tap into the goldmine of selling technology, it appears clear that we are likely to continue to be exposed to more technologies in the near future than we will immediately know what to do with. As archaeologists, that we will need to try to stay with, and if possible, ahead of the times in order to maintain our relevance in such a world. The advent of 3D printing and imaging technologies presents us with this kind of challenge.

3D imaging technologies consist of any type of scanning procedure of a physical item which, initially at least, results in some form of digitized replica, existing purely in digital space. The scanning process can be done via a number of methods including but not limited to 360 degree photography, microCT scans, or MRIs[7]. These digital files can subsequently be 3D printed, resulting in a printed replica of the original item. This physical replica may or may not be a 1:1 copy of the original. Described in this way the process sounds much simpler than it really is--it is worth highlighting the fact that the time-consuming and meticulous nature of this process is often overlooked by the media when discussing these technologies.

The terms replica and reproduction are often used synonymously in the literature as well as in common discussions about 3D printed objects. In order to avoid confusion when

[7] Ahmed 2014; Akca 2007; Bathow and Breuckmann 2011; Bathow and Wachowiak 2008; Breuckmann et al. 2009; Mafart et al. 2002

discussing different methods of artifact duplication, I will use 'replication'/'replica' to refer to all 3D imaged models and 'reproduction' to refer to all other imitation methods. Traditional methods in reproduction include casting, experimental archaeology, or expert recreation. Casting involves taking some sort of mold of the original historical object (via silicone, etc.) and creating a copy from that mold. This method is most closely related to 3D replication. Experimental archaeological methods as well as expert recreation duplicates generally involve re-enacting the same procedures used in the past, which result in a copy made out of modern materials based on historical strategies. Finally, 'object' will refer to any modern object whereas 'artifact' will be reserved for any item of an historical or archaeological context.

Over the past several years, work has grown rapidly in attempts to get the most out of 3D imaging technology, including among archaeologists and historians, worldwide. Most work tends to be focused on revealing what the technology is capable of and less attention has been paid to deeper issues related to this technology, such as ethics, theoretical analysis, and restrictions of practical use. From reviewing the literature and media surrounding this topic, it was clear that the advent of 3D imaging technologies is changing how the world sees, understands, and utilizes modern objects--an idea which will be explored further within this chapter. The subsequent use of this technology in archaeological contexts has meaningful implications for how we as a discipline interpret, conserve, and conceive of archaeological materials. In light of this technology, where once a handful of endorsed reproductions may have been present in universities or museums, now anyone with access to an artifact or to the data from the 3D scan of an artifact, 3D printer, and the time to print, can possess a replica. These replicas are not generally restricted once a scan has been made and released, resulting in

the capacity to be altered in size, colour, or reduced to selective fragments according to the choice of the one who is printing. I shall emphasize the importance of this ideological shift for archaeology and the public's interaction with these replications by analyzing current movements in 3D printing, what these foci mean for our archaeological applications, and what should be done to incorporate any new ideological frameworks for interpreting and using replicas within the discipline. I will argue that we need to understand the place this technology and its products will have in our discipline moving forward; how it will affect our interpretive structures, our research, and subsequent public interests of "accurately" printing the past.

In May 2014 I visited both Disneyland and Universal Studios in California. During my trip I was drawn to their displays of history--materially and otherwise. I was struck by the differences between their depictions; Disneyland appeared to try to stay affixed in an eternal 'now'-ness almost devoid of history, whereas Universal Studios, in contrast, maintained a vast number of tours and areas purely devoted to the history of the studio. What Disneyland did have on display at the time was an 'exhibit' devoted to the *Avengers* movie which had recently been released. While touring the 'exhibit' I observed that the majority of the attention by visitors was paid to the reproductions of Tony Stark's Iron Man suits. These suits were arranged in such a way to mimic Iron Man's showcase room from the films, and could be directly interacted with and photographed without obstruction. Off to the side, and almost ignored, were actual props from the movies which were kept inside traditional museum glass cabinetry. As people walked through the area they were instantly drawn to the suit display rather than the 'historical' artifacts. In contrast, Universal Studios had countless artifacts on display which were placed strategically alongside reproduced props and scenery throughout the park to ensure seamless

attention from visitors. For me, this real life example of the dichotomy between real and replica was striking. In it I saw some possible future issues of 3D replication and our engagement with material history. When the choice to view a replicated object versus an original artifact is given, how does one choose which is more 'worthy' of our attentions? Is it purely based on presentation or context? Will the ubiquity of these 3D replicas overtake and shift the meanings of the original pieces or will they develop an entirely new system of meanings unto themselves--a hybrid of what they are versus what they were made to represent? A synergized future for our archaeological materials seems favourable--to at once replicate artifacts but also maintain their meaning and importance.

This topic is particularly timely due to the pervasiveness, accessibility, and fascination with 3D imaging technologies and their creations in the public eye and academic communities[8]. With so many items already being replicated via these means, at such a fast and widespread rate, it is vital that we understand how interacting with these objects changes about how we see and understand the world through items. 3D printing technologies have already been welcomed into archaeology as an alternative to traditional reproduction, conservation, and education platforms, such as at the Smithsonian and other institutions[9] as well as for politically tense climates[10] and other practical applications[11]. Over the past few years interest within the discipline has focused primarily on what 3D printers are capable of; subsequently discussion

[8] Ramirez 2014; Schaffhauser 2015; Waibel 2015
[9] Afzal 2013; Clark 2013; Flaherty 2012, Neely 2013; Schaffhauser 2015; Sustainable Archaeology 2015; Wachowiak and Karas 2009; Waibel 2015
[10] Milward 2015; Smith 2015
[11] Ahmed et al. 2014; Griffin 2015; Akca et al. 2007; Bathow and Breuckmann 2011; Bathow and Wachowiak 2008; Breuckmann et al. 2009; Melnikova 2014; Postrel 2015; Varin 2013

has turned to ways to incorporate their capabilities into our methodologies both in the field and lab. In reviewing the literature it quickly became apparent to me that archaeology would benefit from subdividing its focus on 3D imaging into three distinct areas of application, practice, and theory: (1) art and entertainment, (2) reconstruction and conservation, as well as (3) research and education. This thesis will focus on the implications for research and education after briefly covering stories from each category to showcase the need for such division.

While many projects will span more than one of these three areas, it is important to understand the different needs, goals, and approaches to 3D imaging which necessitate different focal systems. The Smithsonian's X 3D project is a perfect example of a venture with multiple foci[12]. While simultaneously providing entertainment and access to their collections in a digitized space for the public at large[13], it is also focused on aiding in research and education[14]. Their website includes downloadables of select items for enthusiasts at no cost. While their full catalogue is not up for public consumption at this time, their goal is to have all "…137 million objects, artworks and specimens…" eventually digitized. "...[C]apturing the entire collection at a rate of 1 item per minute would take over 260 years of 24/7 effort[15]." As a result, only a smaller percentage is currently prioritized for digitization. Such a large undertaking shows how relevant an exploration of 3D imaging technology is, but also its implications for collections on a global scale. If it would take over 260 years at a currently impossible processing speed to digitize the Smithsonian`s entire collection (which of course does not factor in any new items

[12] Afzal 2013; Varin 2013; Waibel 2015
[13] Waibel 2015
[14] Varin 2013; Waibel 2015
[15] Waibel 2015

being added to said collection within 260 years) then, to digitize the world's collections at this time is nearly inconceivable. Thus, the advent of 3D imaging and its implications are only beginning to be tackled in this field. In addition, while it has an entertainment component, it also is largely valuable for research and education. One is left to wonder how best to place such a project. Whose goals or needs take precedence? Ought it to be left to the researcher, the project leader, or the user to decide? In the end, whichever categorical focus best suits the primary needs of the venture ought to be chosen, even if divisions are gradated rather than clear-cut. I will now show how these divisions work and how some projects may be categorized within them.

1. Art & Entertainment:

The issues raised by 3D printing of archaeological artifacts for art and entertainment tend to be more ethical than theoretical or methodological, and are not a primary focus for my research. However, some research and education, as well as conservation and reconstruction stories contribute to art and entertainment discussions. An artist named Morehshin Allahyari[16] for example, combines issues of art and entertainment with conservation and reconstruction within her *Material Speculation: ISIS*. It is "...a digital fabrication and 3D printing project...that inspects Petropolitical and poetic relationships between 3D printing, Plastic, Oil, Technocapitalism and Jihad[17]." Primarily an art project and thus art and entertainment, this venture attempts to replicate select items which were destroyed by ISIS this year, classifying it as conservation and reconstruction as well. "...[It] creates a practical and political possibility for

[16] AJ+ 2015
[17] Allahyari 2015

artifact archival, while also proposing 3D printing technology as a tool both for resistance and documentation. It intends to use 3D printing as a process for repairing history and memory[18]." A similar project has been attempted by archaeologists more recently to capture ancient sites destroyed by the extremist Islamic state[19]. While their goals of reconstruction and conservation are the same, the methodologies, approaches, and motivators differ greatly. This archaeology project is also backed by both Oxford and Harvard in an attempt to prevent history from being lost[20]. In order to understand the complex networks of meaning-making which are present in both of these projects, as well as their primary classification as art and entertainment or conservation and reconstruction, we have to understand the underlying relationships between original items, replications, reproductions, and how they act upon us, which will be discussed later.

2. Conservation & Reconstruction:

In 2012 Harvard's Semitic Museum was using 3D imaging technology to recreate a smashed ceramic lion using "photomodeling." This process involved taking pictures of the fragments from hundreds of angles, rendering each piece, and forming a semi-complete digital model of the original artifact that could subsequently be printed[21]. Conservation and replication have also taken place with the Winged Victory of Samothrace to commemorate the 151st anniversary of its excavation[22]. While this project has an art and entertainment flair, the level of detail put into the replicas of the Winged Victory place it more solidly in the conservation

[18] Allahyari 2015
[19] Smith 2015
[20] Milward 2015; Smith 2015
[21] Flaherty 2012
[22] Griffin 2014; Grunewald 2014

category. These articles also describe the intricate process needed to make 3D replicas in detail and some of the ways this technology can be utilized in restoration, conservation, research, and education--repair and resurfacing in particular[23]. This echoes the project started in 2012 by Harvard, and shows that despite the exponential growth of the technologies, by 2014 and continuing to today, there has not yet been a widespread implementation of these conservation or reconstructive techniques. More recently, an artist named Cosmo Wenman, inspired by academic works on the subject, sought to try to reconstruct the *Venus de Milo* to show the possibility of her originally being depicted as spinning thread, an idea advocated by an archaeologist named Elmer G. Suhr during the middle of the last century[24]. While an excellent example of experimental reconstruction, it again is backed by an artist which is problematic. According to Postrel's article[25], Wenman is an advocate for publicly available 3D digital scans of public-domain sculptures, arguing that it would "...allow artists and others to remake existing works in imaginative ways[26]." This sentiment raises concern for the state of "genuine" 3D replication in the future.

3. Research & Education:

There are less politically complex projects currently underway in both conservation and reconstruction as well as research and education 3D imaging. Across the web and various academic articles, applications of and advocacy for 3D imaging technologies are common. A number of museum-focused groups in particular look to the technology as a means of

[23] Griffin 2014; Grunewald 2014
[24] Postrel 2015
[25] Postrel 2015
[26] Postrel 2015

incorporating touch into museum experiences--something which is traditionally missing on a large scale[27]. Digital imaging also is expected to change how artifacts and historical stories are told[28]. Jamestown and Virginia Commonwealth University have teamed up in order to use replicated and painted objects for teaching tours. Their printer is located in an exhibition area for visitors to see and is used primarily to copy local artifacts from active Jamestown sites[29]. Similarly the website PaleoTEACH promotes and sells 3D technology services and replicas to use in teaching[30]. 3D imaging and printing are also being used for experimental research purposes at Texas State University[31] and Jamestown[32]. While the former seeks to use replicated objects in place of originals, as well as for experimental use reconstructing debitage in order to gain greater knowledge of stone tool production[33], the latter has used CT scans to digitize and print the interior of a sealed box thus gaining the ability to study its contents without destroying the box itself[34]. Similar work has been conducted by Andrew Nelson at the University of Western Ontario to see how wooden prayer beads were made as well as taking a non-invasive closer look at the insides of mummies[35].

The Ties that Bind:

In surveying these categorical case examples I hope I have shown how these projects are united in their combining history and 3D imaging, but also a little as to why their diverse needs,

[27] Neely and Langer 2013
[28] Clark 2013
[29] Aronowitz 2015
[30] PaleoTEACH 2015
[31] Speer 2014
[32] Zeffler et al. 2015
[33] Speer 2014
[34] Zeffler et al. 2015
[35] Sustainable Archaeology 2013; Wade et al. 2011

goals, and approaches warrant subdivision. To reiterate, it should be clear that each sector has a different relationship with artifacts as well replicas, and thus a need to be studied in its own frame of understanding. To try to analyze the phenomenon as the whole without accounting for these intricacies would result in a loss of data. It likely would also lead to sweeping rules and regulations which do not adequately serve the diverse needs of these ventures. While standardized regulations and analytical frameworks are necessary for reliable research, it is also necessary to have guidelines which are tailored to specific categories of needs. As stated previously, each of these categories are divided based on the individual goals and needs of a project. Art and entertainment might only be focused on scanning and printing for promotional materials or artistic renditions of the past. Their projects would subsequently be less concerned about attributes such as "accuracy," "authenticity," or high quality detail. In contrast, research and education-based platforms would likely be focused on "accuracy," "authenticity," as well as high quality details in order to be used successfully in classroom settings or as research materials. Taking these attributes one step further, conservation and reconstruction would likely be the most concerned about detail and avoiding data loss, as well as focusing on artifacts and materials in greater danger of loss than the other two categories. Conservation and reconstruction would also likely be interested in artistic interpretations, within historically accepted ranges. It might be best to consider the three categories then as a Venn diagram of options, each with overlaps onto another, and all sharing certain interests and limitations stemming from 3D imaging technologies more broadly.

Issues of ethics, authorship, context, and information regulation affect all three categories to varying degrees. Ethics is perhaps the most important of these and arguably

affects them all equally. Those involved with the Sustainable Archaeology joint project between the University of Western Ontario and McMaster University are beginning to look at some of these more complicated ethical issues of 3D imaging technologies. They advocate a need to move beyond whether or not we *can* do something but rather, whether or not we *should*. By involving local interest groups and stakeholder communities, a chorus of voices has been implemented in order to try and establish an ethical framework from which to produce, analyze, and store 3D imaged replicas[36]. Ethical issues can stem from questions of authorship and control of information: who controls these images and how might they be used? Some items are considered sacred by descent groups and thus may be strictly limited in their replication, if replication is allowed at all. The goal here is to incorporate the voices of descended groups who lay claim to the artifacts we study and avoid neo-colonialist tendencies in research or artifact display[37].

Context and Background:

In order to understand how our concepts of artifact and replica are changing due to 3D imaging technologies, we must uncover the variety of meaning-networks which come together within a 3D replica. In order to do that, it is best to utilize three different theoretical frameworks: object-meaning, archaeological, and anthropological. Our understandings of the meaning-networks encapsulated within a 3D replica are the result of a crossroads between these disciplines and our traditionally conceived people-object relationships. Object-meaning theory

[36] Ferris 2015

[37] Cameron 2007; Clifford 1993; Dudley et al. 2011; Ferris 2015; Hallam 2000; Janes 2007; Keesing 2006; Lonetree 2009; Reisinger and Steiner 2006

seeks to understand our conceptions of objects as though interpreting a language[38]. Archaeological theory is a liminal framework which attempts to synergize ideas about the past and archaeological record with interpretive models as well as quantitative and qualitative methods that are relevant in contemporary society--at once saying something about the past and present contexts[39]. Finally, anthropological theoretical models seek to understand how the day-to-day lives and networks of meanings of different cultures or subcultures develop and reinforce themselves by the acts of living within a given culture or subculture[40]. Anthropology excels in deriving meanings from behaviours and intricacies often overlooked by other disciplines. Through a reflexive look at these theories, we can use their methods to find a way to make sense of the complicated relationship between material cultures, their items, and how they in turn are affected by new 3D imaged technologies.

One of the ways we have to understand objects and their meanings in contemporary settings is to utilize the tools of semiotics, or the study of meaning-making, and object-meaning theory. As discussed by Berger[41], it was first developed by Saussure and Charles Sanders Pierce. Semiotics helps us to interpret items and their meanings as if they were another language unto themselves. Saussure's 'signifier,' and 'signified' are combined with Pierce's 'symbols,' 'indexes,' and 'icons' to form a coherent system of object-meaning analysis. When used together, these approaches help us to see items via the way they exist as signs and generate meanings between people--implicitly or explicitly. In this way, nothing has meaning in itself, as

[38] Berger 2009
[39] Johnson 2010
[40] Lemonnier 2012
[41] Berger 2009

an object's meaning always comes from the network of relations it belongs to in its current contexts. It is clear via object-meaning theory that objects are active and can affect change within us, especially when a shifting of a context networks occurs, changing how underlying object-based messages are sent[42]. With this in mind, 3D printed objects may hold the potential for a *tabula rasa* of meaning-networks. In the process of its reproduction it at once can become an object unto itself with no inherent meanings and at the same time it also is meant to represent everything that the original artifact had. In this way, while one may interpret replicas as Pierce's icon or symbol of the original artifact and its network of understandings (particularly with high-profile originals), those ties are not guaranteed out of context for lesser known pieces. Similarly, while a replica may be considered to be a signifier, using Saussure's classification, it is perhaps more closely related to the signified as it is designed to duplicate an original artifact as closely as possible, thus becoming a signified object itself[43]. A layperson could pick up a well-made replica and have no knowledge of its ties to an original artifact, and even perhaps assume it to be an object unto itself, thereby resetting any signifier/signified or icon/symbol/index meaning-networks which may have been transferred in the replication process. While this may also be true of any "real" artifact picked up by someone untrained in its specifics, the idea remains that if the person observing would not be able to tell the difference between replica or original without the guidance of someone who is trained, that replica may develop its own meaning-networks possibly in parallel with or in even in complete to those of the original artifact. Of course, as soon as any item, replica or otherwise, is comprehended in the mind it is

[42] Berger 2009
[43] Berger 2009

bound by someone's internal semiotic system, but in the case of a replica, this does not guarantee a connection to any specific meaning-networks bound to its original.

According to Clotaire Rapaille[44] in his book The Culture Code, as children we are imprinted with the cultural meanings in which we are raised thus developing a reference system in our unconscious minds which we call upon throughout our lives. These encodings vary from culture to culture which he describes via several examples. Through his various case studies, his 'culture code' shows that every artifact or item contains certain national, cultural, or subcultural attitudes which stem from the imprints we learned as children. "These reference systems [then] guide different cultures in very different ways[45]." The meanings of our items are inherently tied to the contexts in which they are produced and viewed. When items are presented to us in specific settings, they are given a variety of contextual meanings. These symbolic transmissions are typically subconscious, and even when we try to avoid them, we are always working within these interpretive systems governed by individualized cultural knowledges. For example, when a patron sees an item out in the open in a museum with no warnings to avoid touching it, a typical museum-goer would assume that it was some form of replica or reproduction available specifically for tactile interaction. In contrast, if the same item were behind a pane of glass, that same museum-goer would be more inclined to assume it was an original artifact if not labeled otherwise. The same item then, depending on context is assumed to be of a different type: original (safety glass, protected, special) versus replica/reproduction (in the open, exposed, common). This commonly trained response to

[44] Rapaille 2007
[45] Rapaille 2007, 11

artifacts and replicas/reproductions is present in most museum visitors and would be equally reflected in gauging laypeople's responses to the Winged Victory of Samothrace replicas[46], versus the teaching tools of PaleoTEACH[47] or high quality replicas of *Homo naledi*'s bones[48].

Object-meaning theory is significant here as it is from within these complex networks of understanding that we begin to form identities, especially when combined with anthropological theory. Items are never items unto themselves but rather only a piece to a much larger web of conceptualization. Historical artifacts should be considered to belong to similar networks, even if those networks are fragmented or long forgotten. Items can be associated with gender[49], wastefulness[50], national identity[51], religion[52], race and ethnicity[53], as well as individualism[54], and modernity[55] in contemporary settings. Cultural products can also inherit meaning via gift exchange, as demonstrated by Marcel Mauss[56], or even change meanings as they transition from place to place[57]. These methods are further complicated when looking at historical artifacts as it is difficult to separate analysis of past specimens from modern cultural understandings--a pursuit which according to Donna Haraway[58] might actually be impossible. In that way it is important to realize that our modern understandings of object-meaning relationships affect how

[46] Griffin 2014
[47] PaleoTEACH 2015
[48] Killgrove 2015; MorphoSource 2015
[49] Martinez and Ames 2007
[50] Hawkins and Muecke 2003
[51] Pocius 1991; Sheumaker and Wajda 2008
[52] Siegel 2011
[53] Lonetree 2009; Woodward 2007
[54] Miller 2009
[55] Dant 2005; Fowler 2010
[56] Mauss 1998
[57] Hahn and Weiss 2013
[58] Haraway1988

we analyze archaeological materials[59]. These complexities of meaning-making are necessary in order to understand how the emergence of 3D imaging and printing affects our interpretation of archaeological goods and replicas.

Via Olsen's[60] In Defense of Things as well as with Haraway[61], we are reminded of the phenomenological element to this kind of study. Our modern understandings and interpretations of the past are enmeshed within the contemporary analytical frameworks which bore them. Olsen[62] claims that often "...people's engagement with the material world in and with things, the materiality of human life has been left...void...Taking into consideration how often things (and tool making) are claimed to be diagnostic of humanity... social scientists 'may have ignored what might be the most distinctive and significant about our species." The problem is, as Olsen later discusses, we are so caught up within our own systems of understanding that it is hard to break through and see what is actually happening. We need to become aware of the world around us and our interactions with it in order to try to understand the meaning networks taking place[63]. By returning to the items themselves, we can relearn a way to view the world[64].

By analyzing early archaeological theory's attempts at organizing different cultures based on the typologies of their artifacts, Fowler[65] discusses the origins of the relationships

[59] Anawak 1996; Mann 2003; Orser 1998; Yellowhorn 2006
[60] Olsen 2010
[61] Haraway 1988
[62] Olsen 2010, 63
[63] Haraway 1988; Olsen 2010
[64] Olsen 2010
[65] Fowler 2010

between identity and material culture. As Fowler[66] then describes, these past archaeological methods were fraught with problems, namely that they ignored the subversive assortment of social constructs which would have acted upon archaeological goods, unlikely to have been preserved in the archaeological record. While these concepts have been explored by processual and postprocessual archaeological theory, 3D replicas require additional analytical tools due to their liminal nature. Which cultural meanings then should be incorporated into the analysis and understanding of 3D replicas? Both the implicit networks of the past as well as modern contexts of replica creation are tied up in their very production. "...[M]aterial culture [is] part of a culture's character, which [is] explained as a result of a combination of environmental factors and historical trends, events, and social political circumstances[67]."This is a reciprocal event because as we consume, experience, exchange, or make objects, so too do those items affect us and those items we interact with in an ongoing relationship. Anthropology's ability to uncover the ways in which we make meaning is key to understanding the liminal place filled by 3D printed replicas; items which at once are removed from their original contexts, and are still inherently and even perhaps inescapably tied to them as well. While unearthed and retrieved artifacts can also risk losing contexts they are permanently tied to the archaeological record in a way that a freshly printed replica never can be. Artifacts will always be items of the past and as a result they will always hold markers of their production (scientifically, artistically, etc.) which will tie them to a specific era and context, independent of a recorded context. While a recorded context will likely provide greater detail of an artifact's origins and other significant details, its

[66] Fowler 2010
[67] Fowler 2010, 355

origins in the past prevent it from being completely lost in the present. In contrast, a replica is born of the now and can completely lose its original context if it is not of a recognizable original artifact. If removed from the meaning-network which ties a replica from its original artifact, it becomes exclusively an item of today rather than of the past.

Where Archaeological Artifacts and Modern Object-Meanings Collide

Currently when an archaeological artifact is retrieved in an excavation it is conceived of as being at the end of its "life cycle." An archaeological life cycle is used to describe everything that happens to an artifact before it enters the ground: from the material gathering process, production, and finally how that artifact ended up at an archaeological site[68]. In truth, the life cycle does not end there. A new chapter begins when an archaeological specimen is retrieved and archaeologists clean, catalogue, and store it. Generally, stored artifacts can be difficult to access for researchers due to the sheer size of a collection, the rarity of the specimens[69], or even budgetary reasons, and strict regulations. Generally these artifacts may be broken or "used-up" items which require some form of reconstruction. After excavation and processing, some artifacts end up in museums or on display but most do not, and adequate storage and accessibility issues still plague the discipline[70]. Many collections are not stored properly, resulting in a loss of potential data. This problem is further exacerbated by unfavourable political climates and war torn countries where many artifacts and architectural features are destroyed or pilfered[71]. 3D imaging and printing is currently being used to help in accessibility

[68] Sutton 2009
[69] Smithsonian 2015
[70] Dewar 1997; Sutton 2009
[71] E.g. AJ+ 2015; Allahyari 2015; Milward 2015; Smith 2015

and the "backing-up" of archaeological specimen data, as discussed previously, and is one of the founding principles of the Sustainable Archaeology Project[72]. 3D imaging technologies hold the potential for widespread, accurate replication and conservation in a way previously unknown within archaeology--something which has significant portents for the future.

Given that 3D scanned and printed archaeological specimens are clearly going to become more and more common in archaeology, and in some cases will be the sole remnants of artifacts that are for whatever reason lost, the need should now be clear for a re-evaluation of our theoretical approaches to replicated items. These artifact replicas hold a keystone place at the nexus between archaeological artifact and modern object-meaning theories. They inhabit the contemporary realm, bound by the technological, social, and ideological elements of the here and now. At the same time, by design they echo the networks of meaning bound to the original artifacts. Rather than dig past these complex layers of understanding to get at the older "good stuff" we should take seriously the need to preserve the integrity of all meanings tied to such objects and recognize 3D printed replicas for their unique status; liminal inhabitants of archaeological research. In order to accurately address these layers of meaning we must develop new ways of understanding their idiosyncratic position. The problem here is a lack of an adequate theoretical framework which can deal with this niche inhabited by replicas. I will now endeavour to show why there is a need for an amalgamated theory from those I describe below, and why using only one theoretical model is not sufficient for dealing with the abstract ramifications of 3D imaging.

[72] Sustainable Archaeology 2015

Reproductions of archaeological artifacts are by no means a new phenomenon. Museums, educators, and researchers have endeavoured to recreate the material past via a variety of methods[73]. Whether driven by a desire to teach a classroom how a projectile point is made, or what the bones of *A. afarensis* looked like, reproductions are already in our discipline. Duplication of important items has also been happening for some time in human history. The ancient Mediterranean peoples, for example, used a form of mass-production casting and artistic reconstruction which served as a way of sending copies of statuary, architectural features, and other important items across the region[74]. While sometimes copies were made and altered[75], many reproductions were made with intent to use systematic physical symbolism to convey specific implicit meanings. Due to differences in technological production, traditional reproductions, do not generally suffer the same theoretical dilemmas faced by 3D printed objects. Older methods of production often result in poorer copies of the originals they are designed to mimic. While generally bearing a strong resemblance to original artifacts, older reproductions are limited in what they can capture about an original piece. The process to produce these reproductions is also generally very time-consuming, and more cost-ineffective than in contrast to 3D replicas. In contrast, 3D imaged replicas can capture more visual data about the artifacts they copy, resulting in high levels of accuracy, potentially less time investment, and mass-distribution potential following that reduced time investment. Finally, while both reproductions and replicas may achieve a visually striking similarity to their original artifacts, they are also independent objects and do not inherently carry the same meaning-

[73] E.g. Rohner 1970; Coles 1979
[74] Montagu 1992
[75] Ridgway 1984

networks as their parent artifacts. When coupled with the potentials for mass-distribution and availability or accessibility, it should be clear that 3D imaging has more theoretical concerns than faced by its predecessor reproduction technologies.

To explore this further, while it may be argued that replicas and casts share similar theoretical issues for interpreting meaning, I would suggest that any issues raised by casting in particular, are encompassed by those of 3D imaging. While all the problems that affect casting also affect replicas, the same cannot always be said in reverse. For example, 3D printed objects once scanned can be distributed, printed, and replicated countless times over, whether or not the original archaeological artifact is still present, without the same image quality loss suffered by casting a mold. A mold cannot be used to reproduce an artifact as many times due to image degradation over time. A scan maintains its quality for replication whereas a mold cannot be made of a cast lest the image get deteriorated further, much like taking a photocopy of a photocopy. 3D scans can also be manipulated *en masse* in a way unknown to reproduction casts. 3D imaging is also more likely to be used on a variety of ancient artifacts, structures, etc., due to the general non-destructive and low risk scanning methods. It is this potential ubiquity, malleability, and accuracy of 3D imaging products which necessitates the need for an amalgamated theoretical framework. It is not simply about how reproductions and replicas are made, but the implications of what they represent once produced.

It is here where we must return to the three foci, as it is the intent behind replicas changes their meaning networks, such as when used for education or research. In a classroom setting or for public interest, many ethical or technical problems surrounding of 3D imaging may only be marginally relevant. Textures, weights, colours, etc. may not matter when one is

simply looking at features or for general learning. In this way, 3D printed artifacts are very useful--allowing for mass production of cheap and 'accurate' products, which are easier to obtain for smaller classrooms and tighter budgets than older reproductions or casting types. While one must be aware of the differences between an artifact and replica, they will not normally change the basic learning process.

For research purposes, the complicated nature of replicas' liminal position becomes more important. Printable data files of the bones of the new *Homo naledi* for example, are currently available online for download[76]. While in this case the quality of the digital scan is unlikely to be poor due to its high-profile status, printing a tangible replica becomes quite complicated. A researcher is bound by the limitations of the scan as well as their available methods for printing. Funding limitations or ease of access to up-to-date printers, computers, and printing materials can affect the research one can do in a way which having the original bones would not[77]. Where more sophisticated printers can produce highly accurate replicas, poorer quality prints are likely to miss significant details which are necessary for research, a problem shared by traditional reproductions. The object itself then is no longer just a digitally scanned copy of the original bones, but is now also bound by the technology and networks which produced it, no different from older duplication methods. However, 3D imaging has the potential for the most accurate, versatile, and distributable replicas than has been previously encountered in reproduction and thus requires new regulations and analytical frameworks to deal with. The process becomes more complicated when dealing with cultural artifacts as well,

[76] Killgrove 2015; MorphoSource 2015
[77] Melnikova 2014

particularly those with living descendant groups. Here, socio-cultural networks of understanding also have to be incorporated and synergized in order to truly understand what 3D replications represent. These meanings will also change depending on who is printing, why or where an artifact is being printed, as well as how that replica will be used afterwards. There are many stakeholders and networks of meaning that need consideration.

Perhaps one of the most complicating factors about replicas comes not from within archaeological contexts but rather 3D imaging on a global scale. It is often a sensationalized topic in the media which has fueled a fascination and "buzz-word" approach to the technology[78]. As a result there are countless blogs, articles, and news media posts dedicated to showing a myriad of its technological applications[79], usually without addressing deeper issues of how using this technology affects our object-meaning relations. In order to understand how our archaeological reproductions fit into this greater network, we need to understand and develop our own reflexive interpretive framework.

As this technology continues to change rapidly, it continues to affect our existing meanings and understandings of both artifacts and replicas. When an ancient artifact is available as a high quality and detailed replica at the touch of a button and extensive printing time later, what does that do to the meaning of the original artifact? It is certainly changed, perhaps becoming more meaningful in the process. Unlike other reproduction methods, 3D imaging may capture the aura of an original piece in a way unrivaled by other methods, except perhaps early photography. This aura, or essence/"something special" observable by an

[78] Alford 2015; Quinto 2015; Tickle 2015
[79] Akca 2007; Bathow and Breuckmann 2011; Bathow and Wachowiak 2008; Breuckmann et al. 2009; Mafart et al. 2002

onlooker, is believed to be unique to the original artifact, lost in traditional forms of reproduction due to cold copying but like the earliest photography, 3D imaging can capture more than just the shape of an artifact. While many scanners are set up to do just that, others have been used to stitch together photographs to create 3D digital sites[80] which by design capture more than just the shape of artifacts. In addition, the way modern scanning takes place echoes the painstaking setup required to produce early photographs. This process captured the subtleties of individuals trying to be still, thus capturing an "aura" on film[81]. While this may be said of traditional reproduction as well, it remains that several pictures or a scan taken over a number of minutes stitched together may be able to capture more than a cast made at a single moment in time. If the quality of a scan is high enough, the replication of Benjamin's[82] aura in 3D imaging may be realized. Save for cleaning up scans, or choosing which aspects deserve finer detail, etc., 3D scans can provide an almost perfect 1:1 echo without as much subjective risk as in traditional reproductions. Benjamin[83] discussed the difference between viewing a great work of art in person versus on television, saying there was just 'something' different about the real thing, another interpretation for its 'aura.' For Benjamin, the true aura of a piece of artwork was contained within the item itself—observable only when in its physical presence. In further analysis, the "aura" can also be interpreted as a socially constructed 'feeling' or 'essence' one has when viewing an item of assumed importance. It is this socially constructed version of aura which can be easily applied to 3D imaging products. While a replica may be

[80] E.g. Prins and Adams 2012
[81] Benjamin 1999
[82] Benjamin 1999
[83] Benjamin 1999

made out of a different material than its original, the ability to interact with a 3D version of an original artifact or object could in the least simulate the original's aura. Even when viewing and interacting with purely digital 3D models of these items, there is clearly something different happening than what occurs when watching something on television versus in person. 3D imaging technologies provide a different experience, if not completely capturing the original aura, it is certainly doing something to echo it with new accuracy. The line between historical and modern item thus continues to blur, furthering replica liminality.

Where do we go from here?

Tying together the theories and issues as presented above, the question remains, where do we go from here? It is necessary now to consider seriously how 3D imaging technologies are changing the way we interact with objects and artifacts, as well as their replicas. Returning to my divisions of archaeological focus in 3D imaging (art and entertainment, conservation and reconstruction, as well as research and education), I now suggest that ease of access to material culture information via 3D imaging will be at the core of the future of research and education pursuits within archaeology. While this is a focus which is important to each area, research and education have the most to gain as well as the most responsibility in trading 3D imaging and replicas. I do not ignore that the other two sectors have concerns with access and distribution of information, but rather that due to space constraints, their issues warrant discussion in a later document.

In 1947 the Dead Sea Scrolls were uncovered. The actual texts and analysis of the scrolls was kept under lock and key for a select number of sanctioned scholars for a very long time--denying access to others to important sections and keeping the research for themselves. A

concordance was published after some time for use by scholars who had been given access to the scrolls themselves. At this point, a biblical studies student at Hebrew Union College used the concordance copy acquired by his institution in 1990 to reconstruct the texts on the scrolls via computer algorithm and release an "illegal" and "unapproved" copy to the world[84]. This breach of scholarly secrecy allowed academics and other interested persons around the world to study the information contained within the scrolls previously locked from them--from this clever use of new technologies. While 3D imaging may not have any revolutionary scan releases under its belt yet, its future within research and education predict a conflicting range of possibilities for an entirely new understanding for information access, item use, and information regulation. Will we grow to expand and develop further gateways of security or openly share the scans of our artifacts?

As has been hinted at throughout this document, one of the most beneficial things offered to us by 3D imaging technologies is the ease of access to archaeological materials in a way previously unknown to archaeological researchers and educators. Just as the internet revolutionised how we communicate and share knowledge, so too does 3D imaging have the potential to change how we research--someday. In its fledgling form, 3D imaging has a long way to go before it will be capable of providing us with original-artifact-level replication prints at our fingertips. First things first, of course, is the need for a digitization of as many (if not all) archaeological materials as are available. While it may be possible to incorporate a scanning process into cataloguing new archaeological materials as some institutions are doing, there are

[84] Grossman 1991

so many materials scattered in museum storehouses, university labs, and archaeologists' own basements that such a task will take a long time to complete properly. There is also the issue, just like the Dead Sea Scrolls, that many academics or departments might not want to have their artifacts so easily accessible. Fearing a lack of adequate regulations, or perhaps in losing control of their data, it is a very real probability that one of the biggest walls to digitizing the world's archaeological collections will not be the time it takes to scan and catalogue but rather the very people that would benefit from such a process (e.g. digital copyright ownerships and distributions). In order to truly benefit from this technology we need to embrace the sharing of artifact collections and data sets--not only when it benefits us but so that it benefits the community on the whole. With a universal database we may hope to uncover new patterns in material culture and the archaeological record across regions previously unknown. Uncovering trade routes, movements of populations, or other untold possibilities may be lurking in our disconnected objects. Access to all artifacts in a digital space, beyond just the ones considered "important" can do nothing but add to our analyses of the archaeological record.

The digitization of these artifacts does not preclude the accurate printing of their replicas. As stated previously, in their current state, not all researchers will have access to quality replicas that are capable of replacing the study of original artifacts. One can hope, however, in the future, that this will change. The original will likely always hold the most research value, accurate replicas could help to reduce research costs of high profile or rare materials--in insurance, transportation, or permissions for example. While we may one day be able to make 1:1 nearly indistinguishable printed replicas, I would argue we could never replace the original artifacts completely. Artifacts will always have a physical attachment to the

past and its meaning-networks in a way in which a modern replica cannot currently reproduce. While ubiquitous access can help change how we see these items, as well as who can study them, the meaning-networks which attach themselves to replicas can only ever mirror those belonging to artifacts. Time will tell if original artifacts will be perceived of as more or less valuable in light of this technological possibility.

Ease of access also greatly affects educational settings. Where previously getting accurate reproductions may have been costly, now the possibility of having each student have their own copy of *Homo naledi* bones is entirely plausible. Beyond that, replicas could become so cost-effective that students could gain access and retain them for study, much like one purchases and keeps a textbook from a course. More importantly than courseware souvenirs, perhaps, is the ability to have tangible replicas on hand at all. One of the most important and yet often lacking component of classroom education is the tactile experience. Beyond accessing scans in a digital environment, the ability to have physical access to course materials or example artifacts could help students retain and understand information in new ways previously unrealistic to incorporate on a large scale in many education settings. Going one step beyond 1:1 (or 2:1, 0.5:1, etc. for that matter) replication, 3D printed items could also help show how more complex artifacts are made. By printing replicas in a jigsaw-puzzle type way, students can be taught by putting it back together or taking it apart. New dimensions for using replicas in this way for education leave a lot of engaging methods for educators to utilize. In addition, original artifacts could still be utilized alongside these replicas where available and students can analyze both to note differences and similarities--a task which will become even more difficult as the technology improves. This too, may suggest the possibility for crowdsourcing our

archaeological materials beyond classrooms or peers. Interested members of the public could scour the records academics may not have the time to review, think are no longer relevant, or perhaps that they believe to be fully analyzed and perhaps provide new insights on our collections.

Extending this further, it becomes relevant to both education and research to consider the kinds of regulations and procedures needed in order to properly incorporate 3D imaging technologies into our discipline. How can we best go about the development of scans and producing of replicas in such a way as to grant authorship and authority to the right individuals or groups? We also then have to consider that research and education require different kinds of access, regulations, and needs than the other two sub-foci. What kind of ownership and copyright should exist on these replicas if used for education and research versus art or conservation? Should we allow for universal access to all available materials or should there be any kind of restrictions? Once a scan is released do we have a way to prevent manipulation of the data? Could we digitally lock files for use at only a specific organization or by pre-approved individuals? Should we even try? How does this affect socio-political climates of our artifacts? Ought we to fear a muddying of artifact discourse if materials are so easily available? Will a democratization of information cause more good than harm? When the dust settles surrounding 3D imaged replicas, whose opinion will sound the strongest about material history? These are but a few of the numerous questions which develop when we consider the regulations one ought to incorporate into 3D imaging use in anthropology, questions whose answers go once again into an ethical context which are beyond the scope of this document to answer. What can be reinforced here however, is the need to develop methods and procedures to answer these

questions and others which arise in the other foci as an active choice rather than waiting to deal with problems once they arise. The ongoing perfecting of these physical forms should not precede the ethical, theoretical, or methodological implications of this technology. It is up to us to recognize both the opportunities provided us by this technology, but also to take responsibility for how we grow alongside it.

Concluding Remarks:

We are facing a new future not only for our discipline but also for the world. We are capable of producing items and communicating in ways previously only found in the pages or minutes of our favourite sci-fi stories. Twenty years ago the idea that something could be replicated from a computer program and produced in a real tangible form was something that we only saw happen on *Star Trek: The Next Generation*. Now, not only are we capable of creating replicas of our artifacts alongside the creation of new items, we are also capable of sending the patterns for those copies long distances to be printed in other locations. While we may not have yet reached the technological level of *Star Trek*'s replicators, holodecks, or transporter beams, we can certainly hope that one day we might get there.

With that in mind then we must ensure 3D imaging and replicas are treated for what they are: new items in a world of possible meaning-networks. These items may have no meanings unto themselves. They are blank slates upon which we ascribe meaning. It is up to us to decide what those meanings will be. As we develop meaning associations and learn to understand them, so too will those meanings manifest new connections within us as an academic community as well as our ties to the public at large. While at one point our artifacts may have stood as dusty reminders of the past, they could now serve as engaging, hands-on tools for

classroom education. Where people may have had to travel between countries or across oceans to see an artifact in detail, now they may be able to hold it in their hands and explore a version of its beauty. It may not be identical to the original, but its value is built upon the original as well as its own independent contexts. A value that is developing and understood more every day. I challenge you to help realize all these potentials of these 3D imaging technologies within our field, but also to ensure we go beyond simply what we can do and move towards holistically integrating this technology into our future. This must start by establishing a unified theoretical framework for analyzing the place that 3D imaging and its products have in the greater network of material culture studies and archaeological materials. From there, we can hope to try and figure out how to satisfy the needs of all three categorical subdivisions of 3D imaging focus from within this theoretical model: art and entertainment, research and education, and conservation and reconstruction. Finally, the local and diverse interests of those people who would benefit or lay claim on 3D imaged scans and replicas needs to be considered in order to ensure public interests are addressed. Whether helping give voice to the voiceless, or at least in ensuring equal access to information produced by their artifacts, it is now that archaeology must see beyond what we can do, and instead, see between the layers of a replica's resin to find the development of new meaning-networks and auras. Ultimately, we will not be able to completely control what happens to our academic materials, 3D scans, or printed replicas but by actively engaging with the more difficult philosophical questions surrounding 3D imaging in archaeology, we can take control and guide the larger conversation about them, academic and public-alike.

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