Promoting a More Interactive Public Archaeology

Archaeological Visualization and Reflexivity through Virtual Artifact Curation

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Making archaeological objects accessible to both researchers and the public is an ongoing challenge for museums and collections repositories. In many cases, curators may understandably restrict access to artifacts that are too delicate to bear repeated, or even any, handling, especially in the absence of dedicated funding for archaeological conservation. The problem of fragility is compounded by the fact that collections management staff often have limited time available to regularly access items from collections on the behalf of researchers (Sullivan and Childs 2003; Warfel 2000). This is especially true if multiple researchers request to see the same items. Yet, at the same time, museums and other

ABSTRACT

Stewards of the tangible past are increasingly embracing technologies that enable digital preservation of rare and fragile finds. The Virtual Curation Laboratory (VCL) at Virginia Commonwealth University (VCU) partners with museums, cultural heritage locations, and collections repositories to create three-dimensional (3D) digital models of artifacts from archaeological sites distributed across the globe. In the VCL, undergraduate VCU students bring a fresh perspective unburdened by archaeological orthodoxy as they use a laser scanner to record artifact details, edit the resulting digital models, and print plastic replicas that are painted to resemble the original items. The 3D digital models and printed replicas allow for new ways of visualizing the past, while preserving the actual artifacts themselves. These forms of archaeological visualization enable the broader public and not just a narrow band of researchers to dynamically and meaningfully interact with rare and fragile objects in ways that would otherwise not be possible, empowering their own contributions to interpreting, understanding, and reimagining the past. We must embrace co-creation through virtual artifact curation and recognize that, while we sacrifice some control over the stories that are told about the past, more stories will be told and shared as pieces of the past become more accessible.

Los administradores responsables de la preservación del pasado tangible están adoptando con mayor frecuencia tecnologías que permiten la preservación digital de hallazgos frágiles y excepcionales. El Virtual Curation Laboratory (LCV), de la Virginia Commonwealth University (VCU) colabora con museos, lugares patrimoniales y repositorios de colecciones para crear modelos digitales tridimensionales (3D) de artefactos provenientes de yacimientos arqueológicos distribuidos por todo el mundo. En el LCV, los estudiantes de licenciatura de la VCU introducen una nueva perspectiva sin la carga de la ortodoxia arqueológica, ya que utilizan un escáner láser para registrar los artefactos a detalle, editan los modelos digitales resultantes e imprimen réplicas de plástico, que a menudo se pintan para simular a los originales. Los modelos digitales tridimensionales y las réplicas impresas permiten visualizar el pasado de manera novedosa, al mismo tiempo que se preservan los propios artefactos originales. Estas formas de visualización arqueológica permiten al público y no sólo a un número reducido de investigadores interactuar de forma dinámica y significativa con los objetos frágiles y excepcionales, que de otra manera no sería posible, otorgándoles el poder de contribuir a la interpretación, comprensión e imaginación del pasado. Debemos aceptar la creación en colaboración (co-creación) a través de la curaduría virtual de artefactos y reconocer que, si bien sacrificamos parte del control sobre las historias que se cuentan sobre el pasado, más historias serán contadas y compartidas, haciendo más accesibles las obras del pasado.

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collections facilities face increasing pressures to make their vast holdings—once off limits to all but a handful of carefully vetted researchers—more accessible to a broader range of individuals, particularly as a way to drive research and to encourage public support to care for items in those collections (Richoux et al. 1994:199).

This paper suggests that virtual curation (the creation of intangible digital models from tangible artifacts and ecofacts recovered from archaeological contexts) provides possible solutions to these problems. Virtual curation helps to digitally preserve fragile artifacts while simultaneously removing material items from behind the glass of museum displays, the depths of collections repositories, and the hands of private collectors by putting them into the realms of cyberspace. Thus, archaeological findings are digitally preserved through virtual curation while their accessibility has the potential to be significantly increased. Following from Simon (2010:278), a primary motivator for creating digital artifact collections should be to support dialogue and active engagement between members of a community and the museums or other collections facilities that serve this community. Through virtual curation, such co-creative projects can embrace a community that is local and global, since artifact collections become unbounded by museum walls. Opening authority to collections is possible when the public and professionals are equal partners in interpreting artifacts and co-create content that embraces multiple perspectives (Bollwerk and Tate 2012:142–143), including that of a vested community, both physical/local and virtual/global.

Moreover, the coupling of open authority with co-creation initiatives—those that place users in a central role that intimately engages them with curated objects—can help the public feel more vested in the collections and their upkeep. MacArthur (2011:56) has noted that:

> These days, the chances of encountering any given museum object online are much greater than seeing it in person. The advantages of digital collections—findable, searchable, manipulable—have now been well documented.... [U]sers … can tag, share, annotate, rearrange, and recontextualize these digital collections. Artifacts that would otherwise be hidden away in storage are reclaimed and rejuvenated by gaining a second life as digital objects. New technologies also make it easier for the community in whose trust the objects are held to help define their meaning and significance—or at least participate in a conversation about them.

Using the recent public outreach efforts of the Virtual Curation Laboratory (VCL) at Virginia Commonwealth University (VCU) as a case study, this paper explores how virtual curation can provide new ways to engage the public. In particular, the paper considers the impact on digital public outreach of using co-creative methods in which different groups come together and share authority to create innovative programs and products.

THE IMPORTANCE OF VIRTUAL CURATION

Digital preservation through virtual curation is particularly important for fragile archaeological items (Means et al. 2013a, 2013b; Means and Young 2000; Warfel 2000). In many cases, it is also more cost effective for researchers to view accurate digital models of artifacts, rather than take the time and effort to travel to a collections facility (Means et al. 2013a). Three-dimensional (3D) digital models not only allow for new, dynamic ways of providing access to the past but also introduce new approaches to visualizing the past. These models hold considerable promise for democratizing interpretation of the past by enabling and encouraging co-creation by scholars and laypeople alike. Digital media created through virtual curation are shareable across the world, and anyone with a computer is able to manipulate the models in multiple dimensions, providing individuals with the ability to generate their own unique insights about archaeological remains (Bowles 2014; Means et al. 2013a). In his *Cognitive Surplus*, Clay Shirky (2010:161) writes that "The dramatically reduced cost of public address, and the dramatically increased size of the population wired together, means that we can now turn massive aggregations of small contributions into things of lasting value." Creating a virtual extension of existing museum collections creates access for a wired population—individuals linked in cyberspace to each other and a vast array of information ranging from the trivial to the profound—that seeks to generate their own meaning from the digital objects that are presented to them in an active, rather than passive, fashion.

Furthermore, intangible digital items can be made tangible again through the power of 3D replication (Bowles 2014; Huber 2014a; McCuistion 2013; Means 2014a, 2014b; Means et al. 2013a, 2013b). Individuals and institutions are able to readily print pieces of the past, creating their own displays, if they wish. With freely available software, objects of heritage are easily recontextualized in creative ways that break down barriers erected between a user and objects in traditional museum exhibits. And all this is possible from the comfort of one's own home. Even if individuals lack their own 3D printers—a still emerging and developing technology for the consumer—they can access online 3D printing bureaus such as Shapeways (2015). Moreover, if they cannot create their own models of archaeological remains, these also can be found freely available online at sites such as Thingiverse (2015) or Sketchfab (2015). The latter site boasts an expanding collection of material from the venerable British Museum (Sketchfab British Museum 2015). The basic notion behind these efforts is to unlock collections housed behind glass and separated by hundreds of miles and encourage visitation by raising awareness not only of the objects but of the institutions themselves. Access to collections is becoming democratized in ways that were once impossible with traditional methods of curating or displaying objects—truly opening authority to the past and making new forms of co-creation possible. The Virtual Curation Laboratory at the Virginia Commonwealth University is aiming to bring this increased access to collections from throughout the world, but especially up and down the East Coast of the United States.

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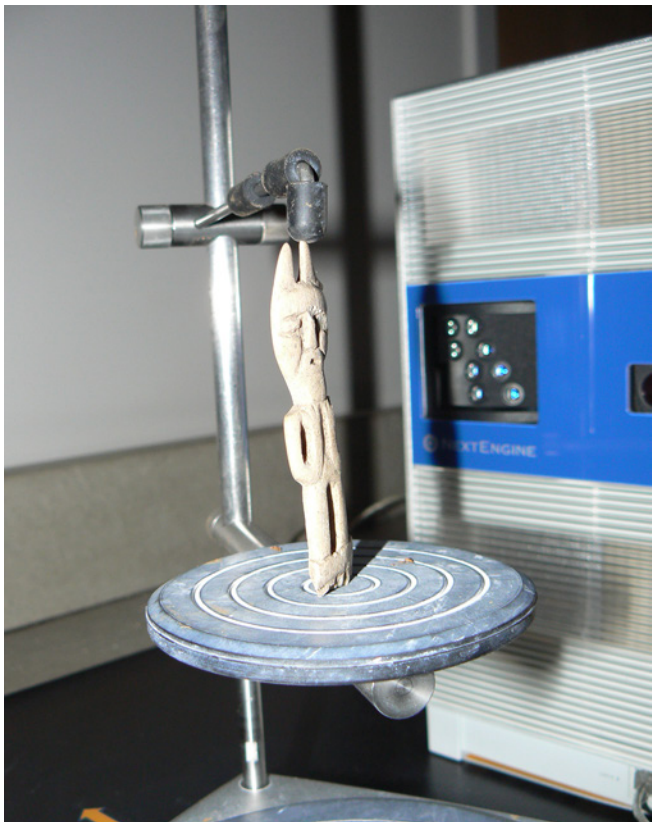

FIGURE 1. Using a NextEngine Desktop 3D Scanner to create a digital model of a Susquehannock bone comb fragment broken during manufacture that is in the collections of the State Museum of Pennsylvania, Harrisburg.

THE VIRTUAL CURATION LABORATORY

In August 2011, the Virtual Curation Laboratory (VCL) was established at Virginia Commonwealth University (VCU) with funding from the Department of Defense's (DoD) Legacy Resource Management Program to explore the application of new technologies to the preservation of cultural heritage resources. Entitled "Virtual Artifact Curation: Three-Dimensional Digital Data Collection for Artifact Analysis and Interpretation," this DoD Legacy Program funded-project (#11-334) was developed in cooperation with John Haynes, then archaeologist for Marine Corps Base Quantico, and an alumnus of VCU, who wanted to ensure that undergraduate VCU students were an integral part of this research project (Means et al. 2013a). The basic goal of this project was to test the suitability of the portable NextEngine Desktop 3D Scanner on as wide a range of archaeological materials as possible (Means 2014a, 2014b; Means et al. 2013a, 2013b) (Figure 1, Supplemental Figure 1).

The NextEngine Desktop 3D scanner uses a series of lasers to capture the topological characteristics of an object by a principle akin to echolocation—the lasers that emanate from the scanner strike an object, are reflected back, and then are recorded by the scanner. The NextEngine scanner also captures a color image of the object that is integrated with the captured topological data. Most objects have to be scanned at least twice, as the hardware used to secure an object onto the scanning platform and the angle of the object prevents the lasers from recording the obscured portions of an object. Complicated shapes such as animal skulls or the bowls of smoking pipes may require three or more scans to obtain sufficient recording angles to encompass the entire object (Means et al. 2013a, 2013b).

The length of each scan depends on the user's preferences for how many data points need to be captured. In the VCL, we use settings that require approximately 30 minutes for each scanning episode. Once a digital model has been created, it requires considerable editing to remove unwanted scan data (the mounting platform, for example) as well as digital noise for each scanning episode, and then the separate scanning episodes need to be integrated into a single digital model. For an experienced user, this process takes from one to four hours, depending on the complexity of the object. Some objects present physical challenges to scanning, especially if they are very reflective or translucent, as these properties interfere with the ability of lasers to capture topological information. There are also ethical issues related to 3D scanning of artifacts, including seeking descendant community permission for scanning objects of cultural patrimony. A more detailed discussion of this issue and the operation of the NextEngine scanner in the Virtual Curation Laboratory, including illustrated tutorials for operation of the scanner and associated software, can be found in Means et al. (2013a) and a brief summary is available online as well (Means et al. 2013b).

Following the conclusion of the pilot project, a new DoD Legacy Program project (#13–134) was funded in October 2013, entitled "Virtual Mobility Archaeology Project with Further Applications of Three Dimensional Digital Scanning of Archaeological Objects." The new and still active project is targeted toward the creation of digital type collections to ensure speedy and accurate identification of materials recovered from archaeological sites on DoD (and other) lands. One digital type collection consists of temporally diagnostic chipped stone tools (Figure 2, Supplemental Figure 2), while the other is a digital zooarchaeological type collection. The diagnostic chipped stone tools included 3D scans of artifacts curated at the Research Laboratories of Archaeology at the University of North Carolina-Chapel Hill that were illustrated by Coe (1964) and at the New York State Museum for artifacts included in Ritchie's (1971) guide to New York projectile points. Much of the digital zooarchaeological type collection derives from the physical type collection at the Virginia Museum of Natural History.

Museums, cultural heritage locations, and collections repositories from throughout North America have opened their collections to enable the Virtual Curation Laboratory to create 3D digital models of artifacts from archaeological sites distributed across the globe, and some locations have shared their own digital artifact models. To date, over 1800 3D digital models have been created from cultural heritage locations significant to American and world history (Table 1). Major research partners that share resources and digital models with the VCL include the Center for Regional Heritage Research at Steven F. Austin State University, the Research Laboratories of Archaeology at

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FIGURE 2. Photograph (left) and digital model (right) of an Adena point (catalog number A-46935.15) scanned at the New York State Museum, Albany. Courtesy of New York State Museum, Albany, NY.

the University of North Carolina-Chapel Hill, the New York State Museum, the Virginia Museum of Natural History, the Smithsonian Institution, the State Museum of Pennsylvania, HNB Garwhal University in India, the University of West Florida, Georgia Southern University, and other locations (Means 2014b; Means et al. 2013a, 2013b; Selden et al. 2014).

The VCL is only one of a growing number of facilities dedicated to preserving the material past through digital means, and these vary from relatively modest operations with one or two low-cost 3D scanners, such as the VCL, to more elaborate facilities with multiple sophisticated means of recording digital data from objects, buildings, and even landscapes. A by no means exhaustive list of these facilities includes:

- Center for Regional Heritage Research at Stephen F. Austin State University (Center for Regional Heritage Research 2015)
- CyArk (CyArk 2015)
- DIVA (Digital Imaging and Visualization in Archaeology) Lab at Louisiana State University (DIVA 2015)
- Idaho Virtualization Laboratory of the Idaho Museum of Natural History (Idaho Virtualization Laboratory 2015)
- Smithsonian Institution's Digitization Program Office's 3D Imaging Program (Smithsonian Institution 2015)
- Virtebra @ UWF ~ Virtual Bones & Artifacts Lab at the University of West Florida (Virtebra 2015)

The VCL is regularly contacted by institutions seeking to initiate their own scanning facilities, or to streamline existing operations. We provided guidance that was used to establish 3D scanning operations at the aforementioned New York State Museum and Research Laboratories of Archaeology, and have freely hosted researchers in the VCL, seeking advice on best practices for 3D scanning from the Virginia Museum of Natural History, Georgia Southern University, the University of West Florida, and West Carolina University, to name a few. Later this year, I will travel to HNB Garwhal University in India to assist with their efforts to digitally preserve the Indian past.

The main reason the VCL is regularly consulted is because we have long maintained a robust web presence (VCL 2011), detailing our successes and frustrations with establishing and operat-

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TABLE 1. 3D Scanning Efforts Outside the Virtual Curation Laboratory Listed in Alphabetical Order.

Location	Details of 3D Scanning Efforts
California University of Pennsylvania, California, Pennsylvania	Created 3D scans of Native American artifacts from Pennsylvania and items from their natural history collection
Colonial Williamsburg Foundation, Williamsburg, Virginia	Consulted with curatorial staff and scanned selected historic items
Council for West Virginia Archaeology workshop, Beckley, West Virginia	Discussed the implications of 3D scanning and scanned Native American artifacts from West Virginia
Flowerdew Hundred Collection, Charlottesville, Virginia	Created 3D scans from Colonial and recent contexts from the Flowerdew Hundred site
Fort Lee Regional Archaeological Curation Facility, Fort Lee, Virginia	Scanned prehistoric and historic archaeological remains currently on display in the facilities museum
George Washington Birthplace National Monument, Westmoreland County, Virginia	Scanned historic artifacts associated with George Washington's father and select Native American artifacts
George Washington's Ferry Farm, Fredericksburg, Virginia	Scanned historic artifacts associated with George Washington, his family, and his family's enslaved servants. Also scanned Native American and Civil War artifacts. Conducted field scanning of historic artifacts and features.
George Washington's Mount Vernon, Fairfax, Virginia	Scanned historic artifacts associated with George Washington and his enslaved servants.
Huntsberry Civil War site, Williamsburg, Virginia	Scanned artifacts in the field recovered from the active excavation of this site.
James Madison's Montpelier, Orange, Virginia	Scanned historic artifacts associated with James Madison and his enslaved servants.
Jamestown Rediscovery, Jamestown, Virginia	Scanned historic artifacts associated with James Fort and a Civil War feature.
Thomas Jefferson's Poplar Forest, Lynchburg, Virginia	Scanned historic artifacts associated with Thomas Jefferson and his enslaved servants.
William C. Johnson collection, Pittsburgh, Pennsylvania	Scanned Native American artifacts from sites located throughout the Middle Atlantic region.
New York State Museum, Albany, New York	Scanned diagnostic chipped stone artifacts illustrated by Ritchie (1971) and other prehistoric and historical objects
The State Museum of Pennsylvania, Harrisburg, Pennsylvania	Scanned historic artifacts and pre-Contact Native American items. Scanned rock art panels.
Research Laboratories of Archaeology at University of North Carolina-Chapel Hill	Scanned diagnostic chipped stone artifacts illustrated by Coe (1964)
Veterans Curation Project, Alexandria, Virginia	Scanned Native American artifacts and demonstrated scanning technology.
Virginia Department of Historic Resources, Richmond, Virginia	Scanned historic artifacts and pre-Contact Native American artifacts. Scanned conserved and unconserved historic artifacts.
Virginia Museum of Natural History, Martinsville, Virginia	Scanned archaeological faunal remains and non-archaeological natural history remains. Compared replica artifact to faunal type collection.
Virginia War Memorial, Richmond, Virginia	Scanned miniature soldiers , World War II artifacts, and World War II veteran Russell Scott
Westmoreland Archaeological Society, Latrobe, Pennsylvania	Scanned artifacts from the American Indian Consol village site

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FIGURE 3. A Virginia Commonwealth University student paints a replica of a dog mandible from Jamestown to enhance its authenticity.

ing a laboratory centered on the relatively low-cost, but sophisticated, NextEngine 3D scanner. At the 2015 annual meeting of the Society for American Archaeology (SAA) in San Francisco, California, I organized a poster session entitled "Crowdsourcing, Co-creation, and Collaboration through Virtual Curation" that included participants interested in developing protocols and pooling efforts to create digital diagnostic type collections and other tools that will aid archaeologists with making quicker and more accurate identifications and enhancing their analyses of existing collections (Card and Spiros 2015; Greene 2015; Killgrove and Zechini 2015; Means and Volkers 2015; Rogers and Stull 2015; Selden et al. 2015; Wood 2015).

The ability to readily share digital morphological models with researchers anywhere in the world is a potentially very powerful tool, especially since there is freely available software for examining the digital artifact or ecofact models from every conceivable perspective—something not possible with static photographs or illustrations (detailed in Means et al. 2013a, 2013b). These digital bone models can also be accurately measured on screen, enabling detailed comparisons between the digital object and the artifact or ecofact being studied by a researcher. The ability to print accurately scaled replicas of artifacts and ecofacts can be particularly important for small research facilities or universities with limited resources or limited space. For example, with a digital zooarchaeological type collection, it will be possible for anyone to assemble accurate animal bone collections—without having any actual animal bones. Accurately printed plastic replicas do not have the storage or preservation concerns of real skeletal elements and can be readily and inexpensively replaced from the source digital models if they are lost, damaged, or stolen (Figure 3). The plastic replicas can also be printed on-demand on an as-needed basis to meet specific identification needs (Manzano et al. 2014; Means 2014b; Means et al. 2013a, 2013b; Zechini 2014a, 2014b, 2014c, 2014d). The benefits of printed plastic artifact and ecofact replicas for outreach and educational purposes cannot be underestimated, as will be considered below (see also McCuistion 2013; Means 2014b, 2014c; Selden et al. 2014).

Our initial concerns, when we established the VCU, were not devoted to using our digital models to encourage co-creative public engagement. Rather, we focused on the technical and logistical challenges of scanning artifacts and ecofacts, and less so on the tremendous potential of virtual archaeological collections to foster a more dynamic and interactive dialogue between archaeologists as practitioners of the past and other people from all walks of life. But, as more and more artifacts were scanned and converted into 3D digital models, and as VCL personnel interacted with a growing number of individuals and institutions who held these objects in trust, it became quite clear that our virtual curation efforts represented much more than a new way to document and make the past accessible to researchers or archaeological professionals.

What was not anticipated with the establishment of the VCL is how central it would become to fostering training and research opportunities for undergraduate students at VCU. In the VCL, virtual artifact curation has become a tool for professional development by undergraduate students in the Anthropology Program in VCU's School of World Studies as they learn collections management, exhibit development, public engagement, research, writing, presentation, and publication skills (Figure 4). These undergraduate VCU students bring a fresh perspective to the preservation and study of the past as they use a portable laser scanner to record artifact morphology, edit the resulting digital models, and print plastic replicas that they often paint to resemble the original items. These students recognize that they are handling, whether digitally or physically, replicas derived directly from unique artifacts recovered through careful excavation, and this gives them a connection to specific past places, events, and peoples. The digital models and printed replicas of artifacts from across time and space have been incorporated into a variety of educational and community outreach settings, providing students with the opportunity to engage diverse individuals, and apply what they are actively learning at VCU.

POTENTIAL OF VIRTUAL CURATION FOR OUTREACH AND CO-CREATION

Some colleagues have questioned whether our efforts are curiosities or novelties that contribute little to scholarly research or public engagement. I argue that virtual curation is ideally suited to foster co-creation efforts between community members with a stake in museums and other cultural heritage locations. Co-creation through virtual curation does depend on what digital artifact models have been created and any replicas printed from them—or that could be printed from the digital models.

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FIGURE 4. Shown from left to right, Virginia Commonwealth University students Brenna Geraghty, Rebecca Bowman, and Lucia Aguilar discuss 3D printed replicas with attendees (out of frame) at the 2015 Middle Atlantic Archaeological Conference.

There are a number of reasons why we have selected what was scanned to create our collection of digital artifact models (Means 2014d).

Initially, as noted above, the VCL was established with funding from the DoD's Legacy Resource Management Program. Our basic goal with this project was to see how effective a NextEngine Desktop 3D scanner would be at creating virtual models of archaeological objects and for its suitability in helping the DoD meet its requirements to archaeology under various federal environmental regulations and laws. These virtual models were seen as a cost-effective way to expand the researcher's access to archaeological material curated from DoD installations and minimizing their need to travel to distant collections facilities. This effort minimizes costs, both for travel and for the time needed by researchers and collections staff to examine and access collections.

For example, the artifact scanning program at the VCL facilitates access to artifacts recovered from archaeological sites at Marine Corps Base Quantico, located in northern Virginia, but stored in the Regional Archaeological Curation Facility at Fort Lee, Virginia, over 100 miles to the south. It is impractical for base personnel or consulting archaeologists to make this journey on a regular basis to examine previous findings. Even if the journey is made, requests for access to artifacts deep in storage are burdensome for the small curatorial staff, who are challenged with keeping abreast of incoming collections that must be organized, cataloged, and stored. Although providing access for 3D scanning also takes time, once an artifact is scanned, it can be readily shared with multiple researchers across the world. For many archaeologists, seeing an accurate digital model of an artifact is sufficient for identification and site evaluation purposes—something not always possible even with the best photographs (Means et al. 2013a). The fact that we are not tied to a particular artifact class, narrow time period, or specific archaeological site enabled us to assemble a wider range of digital objects than would have been the case for more narrowly conceived projects (Means et al. 2013a).

As with more traditional curation efforts at brick-and-mortar museums, the potential for co-creation in the VCL revolves around the assembled digital models that we have created from artifacts and ecofacts. However, as we will address below, the 3D scanning process is amenable to individuals contributing and selecting items for curation in ways that might not be possible with brick-and-mortar museums; the latter often cannot—or at least should not—accept material items outside of their mission statements and their associated storage and care requirements (Richoux et al. 1994). Certainly, while digital data storage is a potential issue, a one terabyte hard drive can accommodate thousands of digital artifact models in a very compact physical

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FIGURE 5. Using a NextEngine Desktop 3D Scanner to scan a lead alloy World War I doughboy miniature at Thomas Jefferson's Poplar Forest, Forest, Virginia.

space, rather than the shelf after shelf of physical artifacts present in a brick-and-mortar museum.

To meet the broadly defined goals of our initial DoD Legacy project, we worked closely with heritage locations and collections repositories located throughout Northeastern North America. After we arrived at a location with our portable artifact scanning setup, we explained the needs of our project and simply asked curators which artifacts they would like to see scanned. Particular emphasis was placed on objects that researchers or visitors most liked to see—creating digital models of rare, unique, or fragile objects would of course help minimize handling that could damage an artifact. We also scanned those objects that people at heritage locations/repositories found particularly evocative of their interpretive mission or that spoke to them in some fashion, e.g., things that are "cool." For example, at Thomas Jefferson's Poplar Forest, we scanned stone pipes made by enslaved Americans as part of the Thomas Jefferson Foundation's mission to highlight all dimensions of this important cultural heritage location—but we also scanned an early twentieth century lead toy soldier that represented a World War I doughboy (Figure 5, Supplemental Figure 3). This toy draws children into discussions of the archaeological discovery process because they can relate such an artifact to their own lives.

The VCL is staffed by a highly motivated and dedicated team of undergraduate students pursuing majors in anthropology, and they all have their own research interests. I am certainly more than happy to accommodate their interests, since this meets our broadest goal—preserving and making the past more accessible. Many students have presented their research at local and international conferences. Virtual curation has served to empower these students and give them chances at co-creation with our digital archaeological models. VCU students interning or pursuing undergraduate research projects have presented their research on the VCU campus and at local and international conferences (Means 2014a, 2014b, 2014c). To date, this research has been published in the pages of the *Journal of Middle Atlantic Archaeology* (McCuistion 2013), the *Quarterly Bulletin of the Archeological Society of Virginia* (Ellrich 2014a; Huber 2014a; Hulvey 2014a; McCuistion 2014a, 2015; Volkers 2014; Zechini 2014a, 2014b), and the *Pennsylvania Archaeologist* (Bowles 2014; Huber 2014b; Hulvey 2014b; Zechini 2014c). The research was also integrated into three Honors in Anthropology undergraduate theses in the 2013–2014 academic year (Ellrich 2014b; McCuistion 2014b; Zechini 2014d).

We have found that digital models of artifacts are very effective for educational endeavors on the K-12 and undergraduate levels, and in public outreach efforts. This is especially true if they have been translated into tangible forms with our MakerBot Replicator printers, which we use to create plastic replicas of our virtual models. For a class of fourth graders at Richmond Waldorf School, in Richmond, Virginia, we have used 3D printed artifacts from sites in Virginia to explain how archaeology informs us about past peoples, including not only early colonists from Europe or enslaved peoples from Africa, but also the state's rich American Indian heritage. Students in Virginia schools generally learn about the state's past in fourth grade, and the plastic replicas enhance the static images in their textbooks. Once sufficient objects and accompanying lesson plans are developed, the printed replicas will be made available to a wider number of teachers.

Particularly effective are chess sets created with pieces reimagined from scanned archaeological items (Means 2014e). Our initial set was developed to pass the time between individual artifact scans and used historic and prehistoric items from George Washington's Mount Vernon, Thomas Jefferson's Poplar Forest, George Washington's Ferry Farm, the Virginia Museum of Natural History, and an unprovenienced find from Washington, D.C. Subsequent chess sets include one focused on artifacts from Jamestown dating from 1607 to 1610 and another drawing on diagnostic chipped stone tools from the Middle Atlantic region. No culturally sensitive materials are incorporated into any of the chess sets. We have used these chess sets, along with other printed and painted replicas of artifacts and ecofacts in a wide variety of public archaeology settings, including Day of Archaeology (2015) events hosted by the non-profit Archaeology in the Community (2015a) and the recent April 5, 2015 Richmond Emancipation Event, which celebrated the 150th anniversary of the city's emancipation. At each public venue or classroom setting where an artifact-themed chess set has been laid out, it draws immediate attention and, as individuals play chess, they are told about the archaeological significance of each piece. How effective these sets are at communicating archaeology in the longer term is not known, and future events will incorporate a way to record these metrics.

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FIGURE 6. A chocolate sculpture of a Venus of Willendorf figurine created by Virginia Commonwealth University alumna Beth Reid is surrounded by smaller 3D printed replicas.

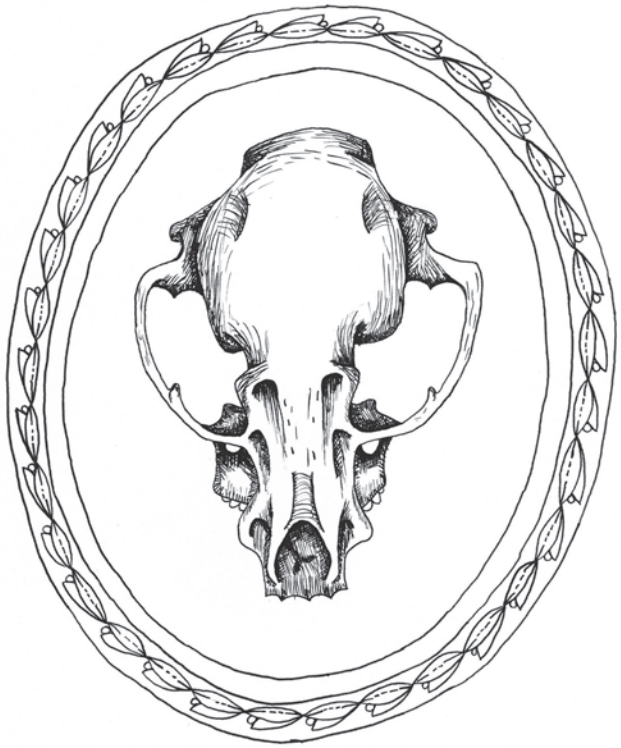

FIGURE 7. Drawing of a raccoon skull by Virginia Commonwealth University student Hanna Bechtle, used as the cover of the *Quarterly Bulletin of the Archeological Society of Virginia* 69 (1).

Applied uses of virtual curation in the VCL reflect an expanding network of collaborative partnerships with individuals and institutions working to preserve and present the past one object at a time and who have encouraged co-creation efforts with the items we have 3D scanned. These collaborative partners are not bound by limitations of time, space, or object type, giving them considerable freedom to select what is 3D scanned by the VCL, rather than having the VCL impose temporal, spatial, or material limitations on our partners. Undergraduate VCU students working in the VCL are also fairly free to select what categories of artifacts and ecofacts they wish to 3D scan, empowering them to make decisions that further their own areas of interest. Limits are placed on culturally sensitive materials, and there are some technical limitations imposed by the types of scanners that we employ, as discussed above (Means 2014d; Means et al. 2013a, 2013b).

However, because of the VCL's expansive approach to virtual curation, projects that are truly co-creative in nature have arisen and appear to be increasing. Our first co-creative project can be traced to an art student—VCU has a very robust arts program—who also had a strong interest in archaeology. As part of an art project, she created a chocolate representation of an Upper Paleolithic "Venus" figurine impregnated with birth control pills—an infertility goddess, as it were (Figure 6, Supplemental Figure 4). There were some challenges with 3D scanning this chocolate "artifact" before it melted, and it had to be kept cold in our department's communal freezer until right before it was scanned with a note that read "Please Do Not Eat." More recently, another art student interested in archaeology used 3D scanned and 3D printed animal skulls to create a series of still lifes, one of which was used as the cover illustration for the issue of the *Quarterly Bulletin of the Archeological Society of Virginia* that featured research by undergraduate VCU students working in the VCL (Bechtle 2014) (Figure 7).

We have been approached by people in the community who have become aware of our virtual curation project in one fashion or another and have contacted us about scanning some of their items. The child of a now former VCU staff member brought us an item sent to him by his grandfather—a mummified juvenile opossum that was found preserved in a corner of the grandfather's garage. We provided the young man with a thorough overview of the VCL, showed him how we could use our reference material to identify his mummy, and explained the virtual curation process from the creation of a 3D scan to its replication using a 3D printer. Within a week, he had a 3D printed plastic replica of his opossum mummy that he was able to take to his classroom show-and-share program.

Since its inception, the VCL has worked with a history teacher at Clover Hill High School who emphasizes the potential of technological means to preserve the past and make it more accessible—although he has focused the efforts of his students on preserving and transcribing letters and other documents (It Took a War 2015). He maintains a small museum in the high school dedicated to World War II, and, at his request, we have created 3D scans and printed replicas of a number of items associated with that conflict. The German bomb fragment from a London bombing site, Japanese soldier's name stamp from the Pacific Theater, and ceramic bowl fragment from Normandy Beach are themselves fairly inconspicuous objects, but are very evocative of a tumultuous time.

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FIGURE 8. Bernard K. Means, standing, uses a Sense 3D scanner to create a digital model of 94-year-old World War II veteran Russell Scott.

Most recently, the VCL has begun working with Virginia War Memorial to record items in their collection, including numerous miniatures, a fragment of World War II barbed wire from Utah Beach, a World War II-era Japanese porcelain hand grenade, and, decidedly outside the types of items normally scanned by the VCL, a 94-year old World War II veteran by the name of Russell Scott. The latter was a truly co-creative venture. Working with an undergraduate VCU history student, then interning at the Virginia War Memorial, I was scanning miniatures one Saturday as part of a miniature show at the memorial when the idea of 3D scanning Mr. Scott arose (Figure 8). The Virginia War Memorial is creating a display centered on a harrowing event in Mr. Scott's life. Russell was a tail gunner on a B-25 Mitchell bomber during the war and was shot down over Italy in 1944. As he escaped the bomber, he sat briefly on the tail, but parachuted to safety, only to be captured by the German army. He became a prisoner of war until he was liberated in May 1945. The Virginia War Memorial has a detailed replica of a B-25 Mitchell bomber that they will display soon, and the VCL scanned the very accommodating Mr. Scott so that we can print a scaled down replica for placement on the bomber's tail.

CO-CREATION AND AWARENESS OF VIRTUAL MODELS

As we work to make digital models of scanned artifacts and ecofacts available freely for download by individuals anywhere in the world, opportunities for recontextualizing the items are limited only by people's imaginations. Of course, people cannot be expected to use these virtual models to make their own contributions to interpreting and understanding the past if they are not aware that these models exist. Our efforts in the VCL at fostering co-creation, reflexivity, and other forms of engagement are challenging because we lack a permanent, physical space related to our virtual curation endeavors—outside of our current tiny and cramped work space.

Raising awareness has relied on traditional and non-traditional means. We make regular presentations and conduct demonstrations at regional archaeology conferences—state-level conferences, in particular, allow us to reach individuals who are not professionals but have a dedication and a passion for archaeology. We also work with history teachers at a local high school, have a student organization focused on virtual curation that hosts events on campus, and have joined with a non-profit archaeology group, Archaeology in the Community, on outreach efforts. Archaeology in the Community produced an Instagram video series "The Dig" that featured objects scanned and printed in the VCL, and these videos were uploaded to Instagram throughout the month of January 2014 and are now archived on Archaeology in the Community's YouTube channel (Archaeology in the Community 2015b). Social media, particularly blogging, is the primary tool employed to raise awareness of the VCL's efforts. With the help of a former student, we began a blog documenting every aspect of the 3D scanning process in fall 2011, from the basic mechanics of how 3D scanning works to detailing our scanning excursions to area heritage locations (Means 2014a).

To enhance the interactive nature of virtual curation—and perhaps inspire co-creative projects—the Virtual Curation Museum website was launched in October 2013 as an extension of the VCL. The goal of this online museum is to highlight research by myself, by undergraduate students working, interning, or volunteering in the laboratory, and by our partners in the heritage and preservation communities. The Virtual Curation Museum strives to make available a selection of the 3D digital models that we have scanned from archaeological sites across the world and place them in an online format that parallels the standard conception of a museum. Unlike a brick-and-mortar museum, we have more flexibility in changing our "virtual exhibit space," and we intended the Virtual Curation Museum to be quite dynamic, with the regular addition of new exhibits and new exhibit halls.

The Virtual Curation Museum was officially "opened" on October 21, 2013, to coincide with a physical exhibit opening at VCU's James Branch Cabell Library in Richmond, Virginia. This temporary exhibit was billed as a celebration of undergraduate research into 3D scanning and archaeology, and was part of my initiative to use the VCL to foster and promote research and presentation skills by my students (Figure 9). Entitled "Digital Archaeology in the Virtual Curation Laboratory: 3D Scanning and Research at VCU," the exhibit featured plastic replicas of artifacts scanned by VCL team members. The exhibit included four panels that are portable and could be moved throughout the library or other campus (and non-campus locations). The four panels were .6 m x .9 m each and had a mix of text and illustrations written by myself and undergraduate anthropology students, but also two atypical additions: (1) plastic replicas of artifacts were adhered to the panels that enabled viewers to

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FIGURE 9. Virginia Commonwealth University alumnae Mariana Zechnini, Ashley McCuistion, and Lauren Volkers (left to right) stand next to a display featuring 3D printed artifacts and ecofacts in the James Branch Cabell Library at Virginia Commonwealth University in Richmond, Virginia.

touch the past; and (2) QR (quick response) codes placed next to the text or artifacts that could take the viewer equipped with a smart phone or tablet to an online museum component. A user equipped with a smart phone or tablet computer could become an extension of the exhibit. We did not see this as a major limiting factor for access to the digital animations, given the ubiquity of smart phones.

THE POWER OF PLASTIC

While I thought that the greatest potential for co-creation through virtual curation was in dynamic digital models, it is the printed replicas that so far seem to capture the attention of fellow archaeologists and members of the public from all walks of life. This should not have been surprising. We hear stories on a daily basis about the promises and perils of 3D printing. The media's obsession with 3D printed guns has quieted down some, and most stories on 3D printing of late focus on how we can use this technology to solve our myriad problems, from using 3D printing to get kids interested in science, to printing body parts such as replacement skull fragments or even organs, to making 3D printed food—shades of Star Trek here—in order to ensure that future space explorers have a varied and healthy diet. Most of this discussion of 3D printing focuses on the creation of some tangible thing—printed in plastic or metal or chocolate or even meat—from intangible digital objects designed almost purely within cyberspace, even if the creator had some real world analog in mind (Bowles 2014). The visceral power of touch cannot be discounted either. Many individuals do not simply rely on visual stimuli to interact with their surroundings, but find the tactile dimensions of their environments equally as important to how they perceive and interact with the world around them (Pye 2007).

Our printed artifacts and ecofacts derive largely from items recovered from discrete archaeological contexts or from faunal type collections used in the identification of archaeologically recovered organic remains (Supplemental Figure 5). These tangible plastic replicas are the same size and form as the originals and can be handled in a manner not possible for the actual archaeological objects themselves. We are currently developing ways of making the creation of exhibits more hands-on for K-12 students and others using basic materials and multiple copies of printed objects. These materials are being provided to teachers for their own educational efforts. The 3D printed artifacts adhered to exhibit panels have engendered interest in the archaeological community, so much so that the VCL has been invited to design a new archaeology exhibit for the Virginia Museum of Natural History to open in Fall 2015. Our most popular application of 3D printing of digital archaeological objects has been the creation of the aforementioned chess

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FIGURE 10. A Susquehannock human effigy from a ceramic vessel is reimagined as a Lego-compatible puzzle.

sets, with pieces created using artifacts that we have scanned (Means 2014e). Individuals who download our 3D digital artifact scans can similarly remix them in new forms—making creations that give a nod to heritage, but in ways that have more meaning to them. Recently, we have begun making Lego-compatible puzzles in the VCL, and these also engender widespread interest in the past (Figure 10). These puzzles involve merging digital artifact scans with digital Lego-compatible blocks and careful editing to create printable puzzle blocks. These were inspired by seeing the ubiquity of Lego models advertised in department store sales flyers.

CONCLUSIONS

The digital models and printed replicas created in the VCL are forms of archaeological visualization that enable the broader public and not just a narrow band of researchers to dynamically and meaningfully interact with rare and fragile objects in ways that would otherwise not be possible, empowering their own contributions to interpreting and understanding the past. As it becomes easier for individuals to access artifacts and ecofacts from archaeological sites across the world via digital means, they can harness the ability to create their own displays about culture and history. The challenge for museums and cultural heritage locations is to establish ties with these individuals that are mutually beneficial. Perhaps someone working out of their own home can 3D print recontextualized artifacts or ecofacts and contribute them to an exhibit at a museum in their community. As 3D printer prices fall, and the technology becomes more user-friendly, virtually curated objects of the past will take on new lives in ways that we cannot even begin to imagine. As outlined by Bollwerk et al. (2015), I consider virtual curation to embody within it the power of both the "*co*," a sharing of digital artifact models, and the "*creation*," the reimagining of digital models in ways meaningful to each individual. We have made only the beginning steps for facilitating this in the VCL, but we see co-creation through virtual curation as an important element on the collaboration continuum.

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Data Availability Statement

The digital data for this manuscript are available through the Center for Regional Heritage Research (CRHR) at Stephen F. Austin State University. The CRHR can be reached through Robert Z. Selden, Jr., Ph.D., RPA, Research Associate, Center for Regional Heritage Research, P.O. Box 13028, SFA Station, Nacogdoches, TX 75962-3028, Phone: (936)468-3953, Email: seldenjrz@sfasu.edu.

Supplemental Material.

Supplemental materials accompanying this article are available online through IngentaConnect: http://saa.publisher.ingentaconnect.com/content/saa/aap

Supplemental Figure 1. Digital model of a Susquehannock bone comb fragment broken during manufacture that is in the collections of the State Museum of Pennsylvania, Harrisburg.

Supplemental Figure 2. Digital model of an Adena point (catalog number A-46935.15) scanned at the New York State Museum, Albany.

Supplemental Figure 3. Digital model of a lead alloy World War I doughboy miniature at Thomas Jefferson's Poplar Forest, Forest, Virginia.

Supplemental Figure 4. Digital model of a chocolate sculpture of a Venus of Willendorf figurine created by Virginia Commonwealth University alumna Beth Reid.

Supplemental Figure 5. Digital model of a raccoon skull scanned from a modern specimen housed at California University of Pennsylvania.

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