

More than just a novelty? Museum visitor interactions with 3D printed artifacts

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Abstract

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Museums have been increasingly interested in ways to apply 3D printing technology. However, little research has been conducted on how the public interacts with 3D printing in museums. The goal of this study is to describe how visitors to the Burke Museum in Seattle, WA responded to and interacted with 3D printed artifacts alongside the originals. I conducted thirty interviews and analyzed both the participants' verbal and non-verbal responses using an embodied interaction framework. Results from this study show that the public is enthusiastic about the idea of museums incorporating 3D printing into their galleries. The data suggest that 3D prints provide an opportunity for visitors to learn from and interact with artifacts through their sense of touch, which is an experience visitors would like to see more of in museums. This study seeks to inform museum professionals on how they can leverage this new technology to enhance visitor experiences.

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Table of Contents

Chapter 1: Introduction.....	7
Chapter 2: Literature Review.....	9
Chapter Three: Methodology.....	23
Chapter 4: Results and Discussion.....	32
Chapter 5: Conclusions and Recommendations.....	49
References.....	53
Appendix A: Coding Categories for Question 6.....	57
Appendix B: Emergent Gesture Categories.....	58

Glossary

Beat gesture: Gestures which do not communicate meaning

Cartesian dualism: A philosophical theory which states that a person is comprised of two separate entities: the mind and the body

Dietic gesture: Pointing gestures which can be enacted by a body part or object

Embodied cognition: An academic movement which seeks to acknowledge the contributions the body makes in cognition

Embodied interaction: A framework which examines the role of the body in how people interact with other people, objects, and their environment

Emergent coding: Coding which groups data into themes pulled from a preliminary examination of the data

Iconic gesture: A gesture which communicates semantic meaning

Chapter 1: Introduction

In the past decade, technology relating to three-dimensional scanning, modeling, and printing has become cheaper and easier to use. The public is enormously fascinated with this technology, and the sale of personal 3D printers has risen dramatically (Neely & Langer, 2013). Some museums are slowly adopting these tools. Museums, including the Brooklyn Museum, the American Museum of Natural History, and the Art Institute of Chicago, host freely available models of artifacts in their collection on websites such as Sketchfab (Sketchfab.com) and Thingiverse (Thingiverse.com), which are devoted to sharing 3D digital files. The Metropolitan Museum of Art also hosted hackathons where the museum invited the public to create 3D models of items in their collection (TrendsWatch2013). Some enthusiastic members of the public have even created their own 3D models by taking pictures of objects on display in galleries and feeding their photographs through photogrammetry software (Steinbach, 2011).

This technology, however, is still very much a new frontier for museums. While much has been written on individual applications of this technology, little systematic research has been undertaken examining the intersection of 3D printing and museums. Despite lowering costs, this hardware and software still could be hard to fit in overstretched budgets. These technologies also require a significant investment in staff time and expertise to use. In addition, many museum professionals see this technology merely as a short-lived novelty. My study seeks to understand the value of one application of this technology in museum settings.

3D printing has the potential to incorporate opportunities for museum visitors to learn through touch. Almost all museums invest resources into facilitating learning experiences for their visitors, and most style their institutions as places for informal learning (Falk & Dierking, 2000). Because 3D printing offers an experience different from the traditional, vision-focused

Museum Visitor Interactions with 3D Printed Artifacts

exhibit experience, research needs to be available on how museums can best leverage this technology to increase visitor learning and engagement.

The goal of the study is to describe how adult museum visitors interact with 3D printed artifacts in context with the originals. I conducted this study to fill in a gap regarding how museums can best use 3D printing to encourage museum visitors to engage with museum collections.

Chapter 2: Literature Review

This chapter examines the literature surrounding the intersection between museums, 3D printing, and embodied interaction. The first section provides a quick overview of the current applications of 3D technologies in museums. The second section examines the how the sense of touch is perceived in museums, which is important for my analysis of how adult museum visitors use their bodies in museum spaces. The third section outlines basic principles of theories of embodied cognition and interaction, which provide a framework for my analysis. The final section describes previous relevant research conducted in museums.

3D Printing in Museums

3D printing is a type of additive manufacturing which builds up layers to create a three-dimensional object. To 3D print an object, a 3D model must be made. This is commonly done by either scanning an existing object or creating a model by hand on 3D software. In recent years, the cost of 3D printers and modeling software has decreased dramatically, which has resulted in increased accessibility for the public (Neely & Langer, 2013). The American Alliance of Museum's publication *TrendsWatch* first identified 3D printing as a museum trend in 2013 (American Alliance of Museums, 2013). Many museums have incorporated this technology into their galleries, public programming, and online presence.

Some museum professionals see 3D modeling and printing as a way to increase participation by engaging museum visitors more deeply in the examination and contemplation of museum objects. Creating a 3D print takes time; a person must take several photos, stitch them together into a model, and then print it out. This process might encourage people to slow down and contemplate museum objects (Neely & Langer, 2013).

3D technology may also provide a unique opportunity for people to personally connect with the museum. By making models and prints, people can curate their own collection of museum objects. Users can manipulate digital models to produce their own creations or responses to artwork (Neely & Langer, 2013). Museums are also uploading scans of their objects to online repositories where the public can download the file and print it at home (Hancock, 2015). Because this technology is primarily digital, the museum visitor can interact with museum objects from their own home, even if they live far away from the physical museum. Moreover, sharing digital models online can be shared over social media and promote new discussions about museum objects (Neely & Langer, 2013).

Museums have also used 3D technology to further conservation and restoration. 3D models can replace photography in condition reporting, resulting in a more accurate depiction of the object in a specific moment in time. 3D printing has also been used to recreate the original look of broken or incomplete pieces (Neely & Langer, 2013).

Museums may stay away from this technology because of the investment in time and money required (Metallo & Rossi, 2011). Allowing visitors to make 3D models or prints of museum objects necessitates that museums give up some control over their collections. Some museums may worry that these activities may infringe on copyright or that they feel it is culturally inappropriate to give the broad public access to high quality scans of artifacts (Neely & Langer, 2013)

Museums may be hesitant to adopt 3D technology, but they should not expect museum visitors to share their hesitance. Software, such as Autodesk's 123D Catch, allows users to create 3D models by capturing images on their smartphones (Metallo & Rossi, 2011). Enthusiasts have already begun to (re)create 3D models of buildings which have been destroyed

by ISIS (Washington Post, 2016). 3D printing technology is still very new, and it will certainly be used in new and innovative ways in the coming years.

Touch in Museums

All material objects contain a mix of sensory outputs. Yet, most museums today privilege sight over the other senses. In fact, most people view the museum as a place for seeing objects, and sometimes have difficulty interpreting these objects with their other senses (Classen & Howes, 2006). This privileging of vision, however, was not always so ingrained in Western culture. Before the mid-nineteenth century, most visitors would handle, hear, smell, and sometimes even eat the items in museum collections. These first museums, both public and private, usually only admitted upper-class visitors who were chaperoned by a curator or guide. Influenced by the ideas of enlightenment science, the educated elite regarded using all senses as vital for seeking scientific truth. Other visitors saw objects as a way to connect bodily and spiritually with people from the past (Classen, 2007). Furthermore, taking time to carefully handle and examine museum objects was seen as sign of intense interest and appreciation for the object (Classen & Howes, 2006). In addition, conservation and preservation was not seen as a priority in the early days of museums. Museum pieces would sometimes be altered or attached in other pieces in order to produce a more aesthetically pleasing object (Classen, 2005b).

Western ideas about the senses, however, began to change with rise of social Darwinism. Some evolutionists began claiming that the defining characteristic of *Homo sapiens* was man's reliance on vision, which was a result of our bipedal stance separating our face and hands from the ground. Other social theorists took this argument and attempted to apply it to modern humans. Nineteenth-century biologist Lorenz Oken argued that Europeans were the most evolved race and therefore had the most refined sense of sight. Further down in the hierarchy, he

characterized Asians as relying on their sense of hearing, Native Americans on their sense of hearing, Aboriginal Australians on their sense of taste, and Africans on their sense of touch (Classen & Howes, 2006).

Moreover, vision was also increasingly seen as the domain of the adult male. Men, when they pursued creative projects, created works of art which were meant to be appreciated visually. Women, on the other hand, created crafts which were meant to be touched or used (Classen, 2005a). Later, Sigmund Freud postulated that children developed by moving beyond a state of infancy, characterized by making sense of the world through the mouth and touch, to a more developed state characterized by learning through hearing and vision (Classen, 2012).

The primacy of sight also influenced academia, especially in philosophy. Eighteenth-century philosopher Immanuel Kant believed that vision and, to a lesser extent, hearing were more objective than the other senses. Kant argued that only by detaching oneself from the body can a person achieve objectivity (Howes & Classen, 2013). This Cartesian dualism, a separation of the brain from the rest of the body, would later be contested by psychologists studying embodied cognition in the twentieth century (Streek, Goodwin, & LeBaron, 2011).

During the nineteenth century, museologists began to argue that museums could provide a public service of educating and civilizing the public. Large, public museums were established and began admitting more people from the lower social classes. These new visitors, however, disturbed the elites who abhorred the thought of coarse, unrefined hands touching high culture. Museum professionals have always been concerned about theft and breakage due to handling, but social convention prevented them from denying upper-class visitors the opportunity to handle the objects. The opening of museums to people from all classes, as well as an increased concern for conservation, provided museum donors and workers a compelling reason to restrict access to

the objects on display (Classen, 2007). The ideal museum visitor would look reverently on works and absorb the culture from afar (Classen, 2005b). This detachment also served to “civilize” visitors by forcing them to rely on their vision, thus socializing visitors into what Westerners at the time thought was a more evolved way of thinking.

Museums in recent years, however, have started to experiment with incorporating sensory experiences in their exhibitions. Museums with cultural collections, in particular, have acknowledged that isolating objects from their original use or context reduces that object to one dimension (Howes & Classen, 2013). In addition, some museums are experimenting with incorporating more sensory information in their exhibits as one way to decolonize the presentation of indigenous artifacts (Classen & Howes, 2006). This experimentation, however, remains rare in museums and exhibits focusing on Western art and culture (Howes & Classen, 2013).

Technology may provide a way for museums to incorporate more sensory experiences. While guided tours have always been a common feature of museum visits, audio guides and video became a way for museums to incorporate sound in the gallery experience starting in the mid-twentieth century. Haptic virtual reality may also provide an avenue for museum visitors to touch objects without subjecting the original to damage (Classen & Howes, 2006).

Hands-on workshops in museums are mostly directed at children, who museums may consider not intellectually developed enough to appreciate objects only through vision (Howes & Classen, 2013). Although everyone learns through touch, the only type of museum which consistently caters to the sense of touch are children’s museums (Classen, 2005b).

Embodied Cognition and Interaction

I use the principles of embodied cognition and interaction to frame my research in this study. Embodied cognition is an academic movement which seeks to acknowledge the contributions the body makes in cognition. This theory stands in opposition to Cartesian dualism, which states that the mind and body are separate, and that cognition arises from the mind alone (Kelton, 2015). Embodied interaction examines the role of the body in how people interact with other people, objects, and their environment (Streek et al., 2011).

Although museums generally communicate information through visual cues, visitors interact with the museum with all their senses. They might feel the chill of the air conditioning, taste the café's food, or hear the click of shoes on the gallery floor. While these sensations are often peripheral to how the visitor learns from or interacts with exhibits, 3D printed objects provide an opportunity for museum visitors to employ their sense of touch to understand museum objects. In this study, I wanted to examine non-verbal cues as well as the participants' verbal answers. Embodied cognition and embodied interaction provided a framework for me to understand how my participants used their bodies, the prints, and the environment to create meaning.

Studies examining the role of embodied cognition show how the body can assist the brain to make sense of the world. Bodily reenacting an episodic memory helps memory recall. This concept may assist educators in promoting learning transfer (Nemirovsky, 2011). Objects, in addition to the body, also can aid in memory recall (Sutton, 2006). In addition, studies have shown that gesture can play an important role in imagination (Nemirovsky, Kelton, & Rhodehamel, 2012).

The role of the body in communication is an important topic in studies of embodied interaction. Gesture is a particularly important way people use their bodies to communicate with one another. Gesture may be particularly potent if, as some psychologists claim, movement is the most basic unit of recognition in the brain. Moreover, the development of pointing gestures in infants is a particularly important developmental milestone, and normally occurs before verbal communication (Enfield, 2011).

Different types of communication serve different purposes (Enfield, 2011). Often, English speakers will say grammatically incomplete sentences, but complete the meaning using a gesture. For example, a person might ask “What do you think of?” and point to the thing to which she is referring. Without the gesture, the sentence is meaningless. In certain situations, gestures can provide a more efficient way of communicating compared to verbal information (Streek et al., 2011). Hand movements, for example, are often better at conveying attributes of size and shape (Enfield, 2011). In addition, indexical (pointing) gestures can compel another person to attend to a visual element, eliminating the need for a detailed verbal description. Gestures, in turn, are meaningless without greater context (Kendon, 1997). In order to make meaning from gesture, the person interpreting the action must take into account verbal cues as well as the environment and social context (Streek et al., 2011).

Non-verbal communication is also socially situated. Gesture is most effective both the sender and the receiver’s bodies to be oriented toward each other (Streek et al., 2011). People use gesture less frequently when the sender cannot see the receiver (Kendon, 1997). In addition, communication is sent with an intended receiver in mind. The sender will change his verbal and non-verbal communication in accordance with his belief about what will be most intelligible to the receiver (Enfield, 2011).

Previous Evaluative Research

While embodied interaction has been used to evaluate interactive computer displays in museums (for an example, see Hall & Bannon, 2005), I will not touch on this literature because my participants only interacted with the finished product of 3D printing, and not the scanning or modeling.

Most museum evaluations using an embodied interaction framework have examined children, perhaps because museums still see touch as primarily beneficial for younger audiences. Renner (2013), in her dissertation, examined how fourth graders engaged with an interactive exhibit in a natural history museum. She analyzed the children's verbal responses as well as gestures and body movement. She found that children used more indexical gestures compared to iconic gestures, and used more concrete language compared to abstract language. Children tended to use the indexical gestures to direct the attention of others to an interesting aspect of the exhibit. They also used indexical gestures to direct their own attention to a particular part of the exhibit. Renner observed children pointing to exhibit text and exhibit elements when no other children or adults were near, suggesting that the gesture was for the child's own benefit. She also noted that touch could play a part in social interactions with other children or adults. For example, some children touched exhibit objects when they wanted to take a turn viewing the object when the exhibit was crowded. Children also showed a preference for touching elements with a higher level of sensory information (such as interactive exhibit elements) versus objects with lower sensory information (such as exhibit panels), suggesting that children seek out these elements because of the information they can provide, rather than touching exhibit elements randomly. Children showed a higher preference for interactive elements (such as a reproduction of a saber-tooth lion skull which the children could open and shut) versus museum objects they

could not manipulate (such as a fragment of a mammoth tusk securely fastened to an exhibit panel). Children also spent more time in parts of the exhibit with interactive elements compared to areas of the exhibit with no interactives. She also found that children may use motion to bodily experience a concept. For example, she observed children sweeping their arms out from their body and back while viewing a taxidermy mount of a condor. This motion perhaps aided the children in understanding the wing movements of the bird.

The observed children usually touched the exhibit elements before commenting on them. Children more commonly touched the elements silently versus touching and talking simultaneously. Gesture was almost always paired with speech. Children were more 2.5 times more likely to talk about an exhibit after touching any part of the exhibit, including interactive portions, museum objects, and even exhibit panels compared to the children who touched nothing. The students used more concrete speech compared to abstract speech. However, children who engaged with the interactive elements of the exhibit were more likely to use abstract speech compared to those who did not engage with these elements. Renner postulates that some museum interactives may be better suited for eliciting abstract responses from children. Most instances of abstract speech in her study occurred at one interactive describing the movement of tectonic plates.

Renner concludes that touch and gesture aided her fourth graders' cognitive engagement with museum exhibition content. She notes that gesture, body movement, vision, and speech act together to create meaning in a child's mind. She argues that these objects distribute cognitive labor, resulting in a more complex cognitive experience for the children involved.

Kelton (2015) in her dissertation, also uses embodied interaction to examine how children think in a museum exhibit. In her case study, she observed school children attending

Math Moves!, an interactive exhibit focused on teaching children about mathematics. In contrast to Renner (2013), Kelton devotes most of her analysis to how the expectations and norms of the school classroom play into the students' interaction with the exhibit. I will not go into these findings here, because they do not directly relate to my study.

Of note in my study is the way Kelton views interactive museum exhibits. Kelton notes that one of the teachers of one of the classes she observed said that she felt the exhibit was “an intriguing novelty”. She sees this teacher's view of the exhibit as an example of how people view the process of learning mathematics. Kelton argues that western culture, influenced by psychology, philosophy, and pop culture views learning math in a Cartesian duality, where the process of learning mathematics takes place entirely in the mind, with no input from the body. *Math Moves!*, Kelton argues, upsets this assumption by demonstrating the role the body has in making sense of math.

There are other studies exploring how visitors interacting with touch in museum exhibits which do not use embodied interaction as a framework. One of these studies is the British Museum's evaluation of their Hands On desks (British Museum, 2008). These stations, located in exhibit galleries, invites museum visitors to touch historic objects and talk with a volunteer. This evaluation measured three aspects of visitors' interactions with these desks: attraction to the desks, engagement with the objects, and visitor motivations.

The Hands On desks attracted more repeat visitors versus first time visitors as well and attracted higher percentages of visitors from the United Kingdom. Families were also much more likely to visit these tables compared to other groups. Visitors spend, on average, about 5 minutes interacting with these tables. 71% of those who visited the desks touched an object.

Museum Visitor Interactions with 3D Printed Artifacts

The main motivation for people using these desks was to touch objects, with listening to the volunteer and asking questions as secondary motivations. Many visitors found the opportunity of holding historical objects very appealing. Families, in particular, enjoyed the opportunity to allow their children to examine objects up close. Visitor motivations were also different for those who interacted with the desks versus those who did not. Museum goers who did not use the tables tended to have more social motivations for coming to the museum, whereas visitors who interacted with the tables tended to be more intellectually motivated. The vast majority of visitors (94%) decided to stop at one of the tables incidentally instead of making plans to visit them before they came to the museum. Visitors had a wide range of motivations for interacting with the Hands On desks. Many visitors mentioned that they appreciated the opportunity to touch objects. Some specifically mentioned that they liked that they could touch historic objects, while others said that they appreciated touching replicas because they did not have anxiety about breaking the originals. The study does not mention the percentage of visitors who preferred touching historic objects versus replicas, but the report does note that some visitors preferred the replicas and some preferred historic objects. Visitors were most attracted to objects which they felt could impart a connection to people in the past. Those who engaged with the desks were also drawn to very old objects, objects which could be changed or manipulated (such as a broken piece of pottery which the visitor could assemble), and objects related to a hobby the visitor engaged in. Visitors tended to approach the desk more frequently when there were already other people engaging with the objects.

The authors of the report note that it was difficult for them to conclude if the tables encouraged visitors to spend more time in the galleries. However, 61% of those who interacted with the tables stayed in the gallery afterward, perhaps suggesting that the experience prompted

the visitor to want to learn more. Visitors indicated that, by interacting with the desks, they learned new knowledge (48%), gained some sort of insight (22%), had an interesting personal encounter (19%), or had a question answered (7%). Nearly all visitors who were interviewed stated that the Hands On tables increased the quality of their visit.

My original inspiration for undertaking this research was Paola Di Franco's work on 3D modeling and printing archaeological artifacts. In her dissertation (2014), Di Franco examined how professional archaeologists and undergraduate students interacted with artifacts which they could touch, artifacts placed in a vitrine, digital models of artifacts, photographs of artifacts, and 3D printed replicas of artifacts. She video recorded these two groups talking to the camera about one of the artifacts in an empty room.

Di Franco argues that archaeological theory is often rooted in Cartesian dualism. She points to processual archaeologists' insistence that culture consists of ideas, not things, and post-processual ideas about how an archaeologist can read artifacts like texts. Di Franco instead draws on the field of cognitive archaeology and embodied cognition to argue that physical interaction with artifacts is necessary to gain a fuller understanding of not only the artifact, but the culture and people who produced it.

In her study, Di Franco found that having a physical object to touch (ie. the artifact or the 3D print) helped students describe the object more fully. Both groups talked about the material composition of the artifact when they could touch the original. Both groups also most frequently discussed texture when viewing the 3D model. Very few people talked about the weight of the object, even if they were able to pick up the original.

Students had more instances of beat gestures, while archaeologists had more instances of iconic gestures. Iconic gestures were most often used when describing the function of the

artifact. The 3D model group used significantly more gestures, both iconic and beat, compared to the other groups. Both students and archaeologists used the fewest number of gestures when the artifacts were housed in a vitrine. Participants in this group often put their hands behind their back while bending over the vitrine to examine the artifact more closely. Di Franco postulates that the case imparted a social distance, and sent a message to the participants to be cautious around the artifacts. Iconic gestures were most often used when participants could not hold a physical item.

I was able to locate one study which specifically addresses museum visitors interact with 3D printed objects. This evaluation analyzed five public programs using 3D printing technology at the Art Institute of Chicago (Neely & Rozner, 2015). In the first program, targeted to families, participants mimicked Indian sculpture using their bodies. Their bodies were then scanned and the visitors could interact or manipulate the resulting 3D model. The second program invited people with Alzheimer's or dementia and those with vision impairments to interact with 3D printed replicas of items in the museum's collection. The third program, comprised of teens, incorporated 3D scanning, modeling, and printing into a larger program designed to investigate the "meaning and value of objects today". The fifth program was a professional development workshop for educators and taught participants how to create and print 3D objects.

Neely and Rozner found participants felt that touching the 3D prints allowed them to connect more with the objects on display and often invoked a conceptual "awakening". Even though the prints did not mimic attributes such as size, texture, or weight, they were still valued and appreciated by program participants. Participants in the teen and educator programs reported that interacting with 3D printing technology prompted them to think critically about the nature of art and making art. Participants also reported greater satisfaction with the program when they

Museum Visitor Interactions with 3D Printed Artifacts

were able to interact with more steps of the 3D printing process (scanning, modeling, and printing). The authors also note that museums which want to incorporate 3D printing into their public programming need to bring in facilitators who are able to explain the technology and tailor their instruction to different levels of interest and expertise. In addition, they note that the ability to be flexible when things do not go according to plan is key when incorporating this technology into programming.

Chapter Three: Methodology

Study Design

The goal of this study was to describe how 3D printed objects deepen visitors' engagement with museum collections. In particular, this study set to examine:

1. What kinesthetic responses, if any, are prompted by interacting with the 3D printed objects?
2. What kinds of gestures do people use when interacting with 3D printed objects versus objects on display?
3. How do museum visitors perceive 3D printed objects in museum environments?
4. Does the materiality of the object (texture, weight, color) affect participants' interactions or feelings toward the 3D printed object?
5. In what ways do 3D printed objects connect present-day people with people from the past?

For this study, I interviewed visitors to the Burke Museum of Natural History and Culture in Seattle, WA. I conducted my interviews over the course of two days: one was on a Thursday, which was free to the public, and one was on a Saturday. My study was qualitative and sought to describe experiences. I used a facilitated interview and I video recorded the participants' responses. I used video because I wanted to analyze the participants' verbal and body language.

Before I conducted interviews, I selected my artifacts and prepared the 3D models. I picked artifacts from the archaeology education collection at the Burke. Using objects from the education collection gave me more access to the objects during the time I was scanning as well as when I was conducting interviews. A downside to using these collections was that most of them had little provenience information, which meant that I often could not share specific

Museum Visitor Interactions with 3D Printed Artifacts

information about the object with the participant. I selected four objects for my study: a metate from Honduras, a harpoon point from St. Lawrence Island, Alaska, a ceramic bowl from Chiang Mai, Thailand, and a pair of snow goggles from Alaska. I picked these objects because I was interested in how museum visitors would perceive the function of these objects. I also wanted objects which people could relate to and imagine themselves using.



Image 1: Alaskan snow goggles



Image 2: Thai bowl



Image 3: Honduran metate



Image 4: Alaskan toggling harpoon point

After I selected my objects, I started the process of making the prints. I decided to use an Artec Space Spider scanner to make the 3D models. Using a scanner, rather than piecing the model together through photogrammetry, cut down the time required to produce the models. In addition, I noticed that the photogrammetry software I was using had difficulty picking up small details. Because the harpoon had very fine etched designs, I decided that the scanner would produce the best result. The highest resolution the scanner can achieve is .1 mm. I scanned small sections of each object on an ethafoam platform resting on a turntable. I slowly turned the turntable while scanning to capture angles. I then flipped the object and repeated the scanning for the other side. I used Artec Studio software to mesh the scans together to create a 360 degree digital model. I then printed the models out on a Makerbot Replicator 3D printer using white PLA filament at 2mm resolution.

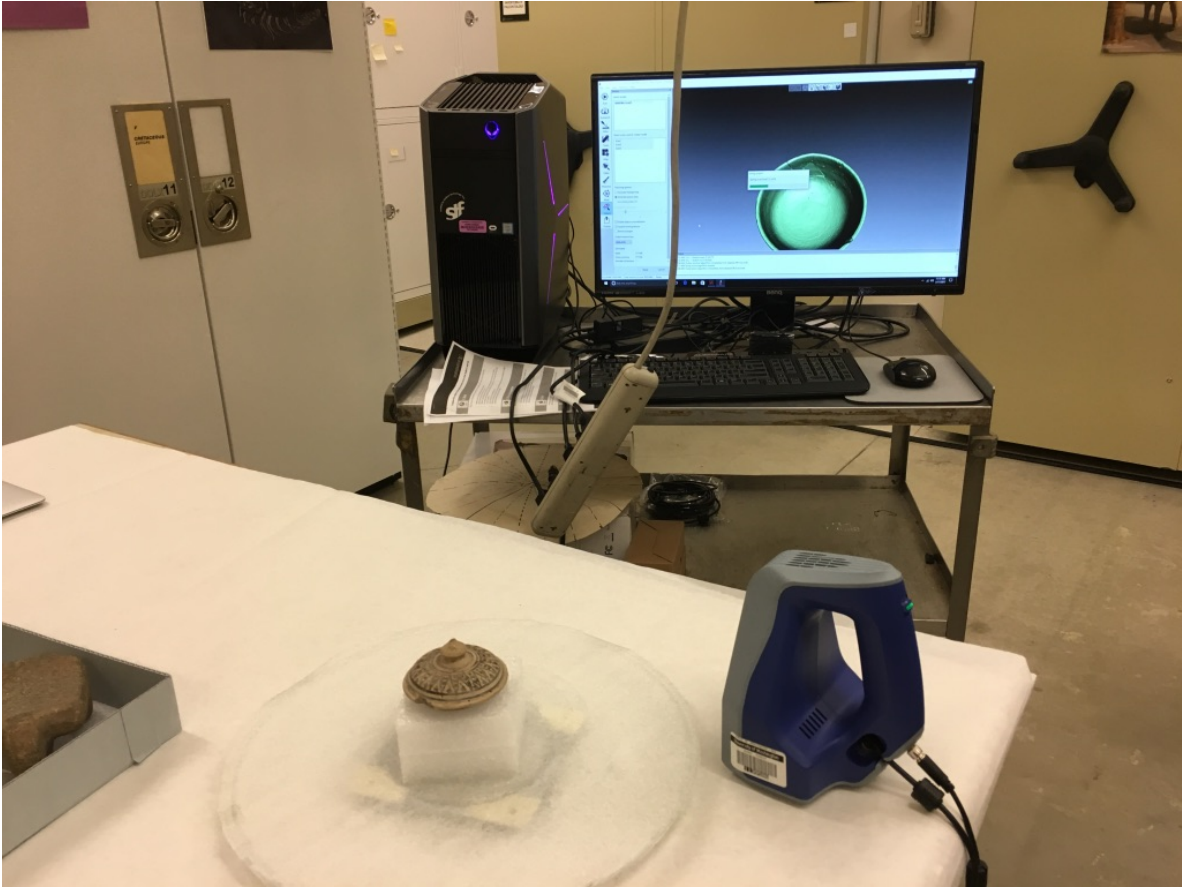


Image 5: Scanning the bowl lid



Image 6: Finished 3D prints

I set up my station in the lobby of the Burke Museum. I had a table with an acrylic glass vitrine in which I placed the original artifacts. In front of the vitrine, I placed each print in front of the artifact it corresponded to. I recorded each interview using my laptop and a webcam.



Image 7: Study setup at the Burke Museum

On the days I collected data, I asked any visitor who came up to my table to participate in the study. Before starting, I obtained their consent to video record the interview as well as confirmation that they were at least 18 years old. I then conducted a semi-structured interview. To make the interview seem less of a test and more of a natural museum interaction, I did not adhere strictly to the interview script. I probed and talked when the visitor seemed interested in a certain topic or aspect of the interaction. After I was done with the interview, I often spent some time chatting with the participants about the other objects on display. These interactions were not included in this study, and I coded the interviews until the participant was done answering the last question of the interview. The interview questions were:

Museum Visitor Interactions with 3D Printed Artifacts

1. What were you thinking when you picked this object?
2. How would you use this object or how do you think it was used?
3. What materials do you think this was made from?
4. Who do you think used or made this object?

[Here I explained what the museum knows about the object]

5. Does this information give you any more clues about the object (did not ask if the participant commented more about the object)
6. What are your thoughts on having 3D prints to touch when you visit a museum?

Coding and Analysis

Because I conducted my interviews in the Burke Museum lobby, I often had participants who came to the museum as part of a group. The participants often interacted with the other people in their group by discussing the questions with other people or passing the prints to their companions. I also interviewed several adults who had their young children with them. Although I only directed my questions to the person who originally agreed to the interview, I did not discourage the participants from talking or interacting with other people. While this provided for a more organic museum interaction, it did make it more difficult to compare the data between interviews. I only recorded the verbal and non-verbal responses of the person who agreed to the interview. I noted where there were interactions with another person, but did not record the other person's responses or actions.

I measured the length of the interview from the time the participant started talking to when they finished their last sentence answering question 6. I then measured how long each participant held or touched one of the 3D prints. I also noted which questions the participant used the print to help answer the question (by feeling, gesturing at, or picking up the print).

I transcribed all verbal responses and took notes on what I said. I coded question 1 based on which item the participant picked to talk about. I analyzed question 6 by first coding their responses into three categories: positive, neutral, and negative. I then used emergent coding to create categories for the reasons they gave. I found that the responses fell into fourteen categories. These categories included facilitating sight, arriving at a new conclusion, and increasing their interest in the artifacts. For a full listing of these categories, see Appendix A.

I observed three types of gesture in my interviews: beat, deictic, and iconic. I decided to not analyze beat gestures because they were too numerous and did not seem to follow any pattern. I initially grouped gestures into eight emergent categories. For a full listing of these gestures, see Appendix B. I then grouped these categories into four larger categories based on if they were iconic or deictic, and whether they were directed to the artifacts in the vitrine or the 3D prints. I distinguished iconic from beat gestures by determining if the gesture was related to what the participant was describing. The verbal affirmation of the iconic gesture could be describing the motion of the hand or the person failing to verbalize what they were thinking and using the gesture to communicate meaning instead.

I was not able to ask everyone all six questions, due to either the participant wanting to cut the interview short or due to my error. Participant 5 was an elderly woman who was not able to speak above a whisper and audio from her interview was not picked up by my recorder. I took notes of what she said, but they were not complete enough to include in this analysis for

Museum Visitor Interactions with 3D Printed Artifacts

questions 1-5. I was, however, able to record her exact words for question 6 after the interview was over, so her response is included in the analysis pertaining to this question, as well as analysis relating to non-verbal communication.

Limitations

I collected data in one location, so my findings are influenced by who visits the Burke Museum. Visitors with a different background or from a different community may behave differently when they visit a museum.

Because each interview varied considerably, broad comparisons across my entire sample are difficult. Each interaction was different based on factors such as the object the participant picked, whether they were alone or in a group, and their previous knowledge of archaeology. In addition, my sample size of thirty interviews is relatively small. This study seeks to describe these experiences rather than generating broad conclusions about museum visitors.

Chapter 4: Results and Discussion

The goal of the study was to describe how museum visitors interact with 3D printed artifacts in context with the originals. I conducted thirty interviews at the Burke Museum of Natural History and Culture in Seattle, WA. These interviews were video recorded, and I used emergent coding to analyze both verbal and non-verbal visitor responses.

Findings

The longest interview was ten minutes and 56 seconds and the shortest was 1 minute and 52 seconds. The average interview length was four minutes and twenty seconds. Thirteen people chose to talk about the bowl, eight people picked the snow goggles, six people picked the harpoon, and two picked the metate. One participant did not want to pick one object and instead talked about all four.

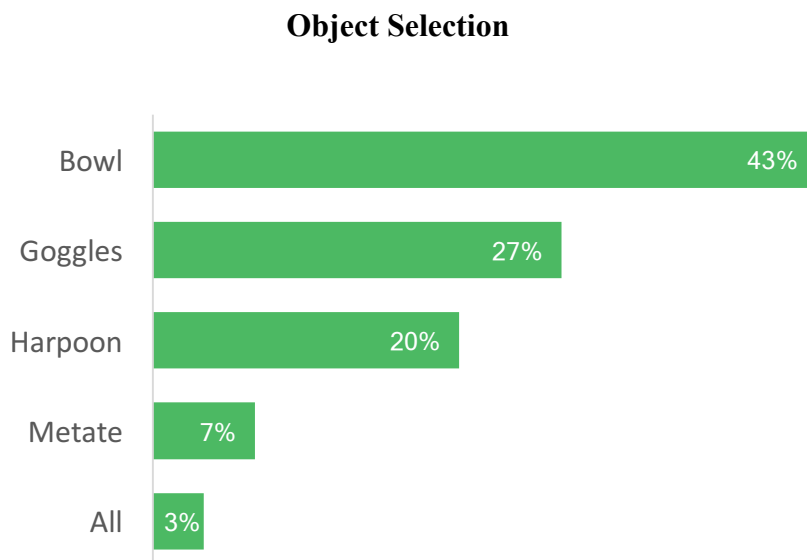


Figure 1, n=30

There was large variation in the percent of time participants interacted with the prints. Two people did not interact with the prints at all, while some participants held the prints for nearly the entire interview.

Percent of Interview Spent Holding or Touching a Print

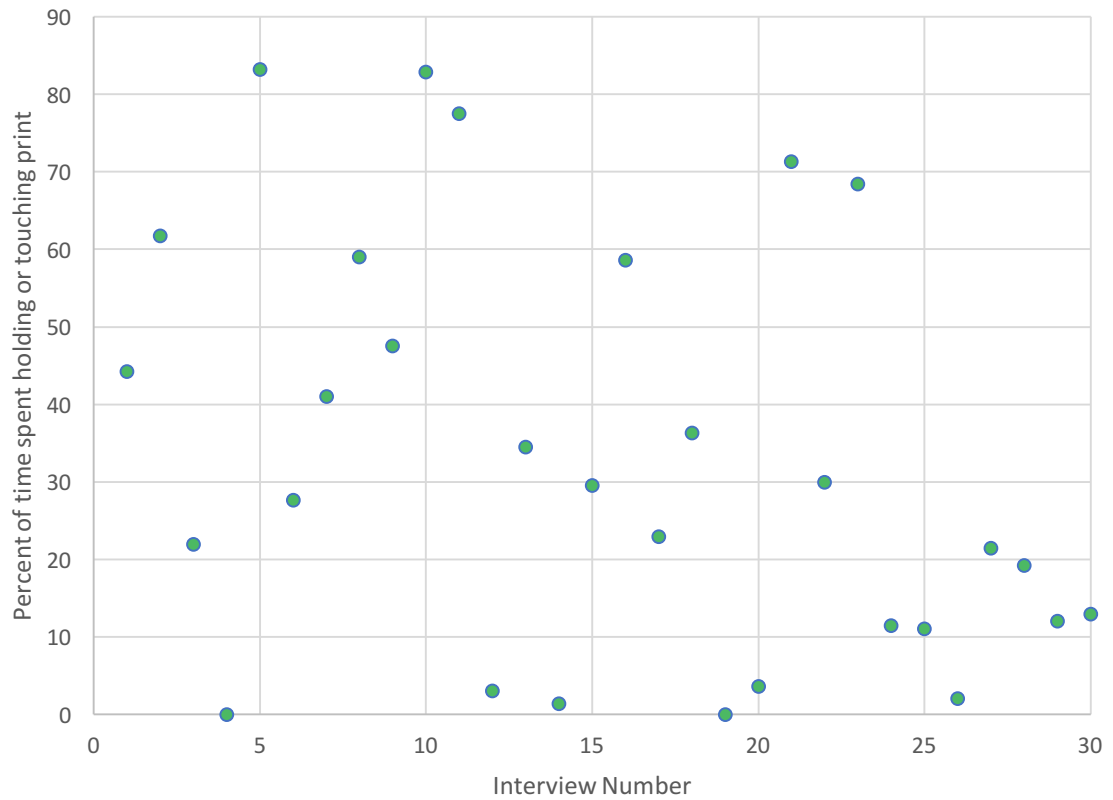


Figure 2

I also recorded which questions the participant used the print to help them answer a question. This can include gesturing to, feeling, or picking up the print. There is a split between participants who used the prints for all questions (12 participants) and those who used the prints for 40% of the questions (6 participants). I used percentage for comparison because I was not able to ask every participant all six questions.

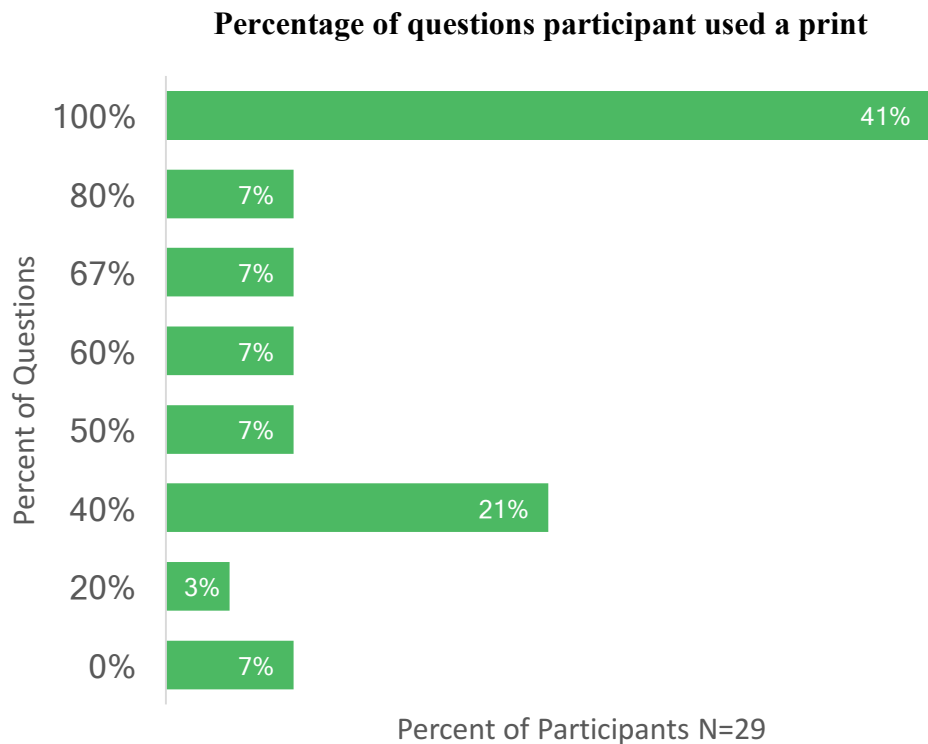


Figure 3

I then examined the different frequencies of using the print based on question. The highest percentage based on question was question 6, which asked “What are your thoughts on having 3D prints to touch when you visit a museum?”. 83% percent of the participants used the print for this question. The second most frequent was “What were you thinking when you picked this object?” at 76%. “How would you use this object or how do you think it was used?” was used 72% of the time, “What materials do you think this was made from?” was used 57% of the time. The only question which the majority of the participants did not use the print was “Who do you think used or made this object?”. 43% of participants consulted the print for this question. I did not include question 5 in this analysis because I did not ask the participants to comment on any particular aspect of the artifact.

Percentage of questions participant used a print based on question

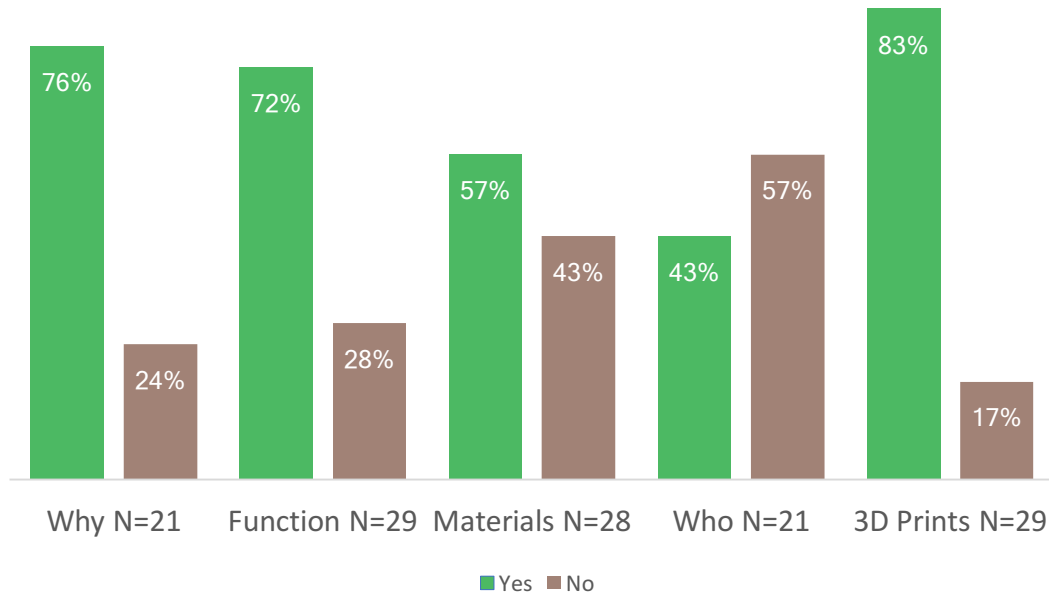


Figure 4

I used emergent coding to break the gestures I saw into several categories. They are defined as:

Show print to me: Participant directs my attention to the 3D print by bringing it closer to my face

Engage with another: Participant uses the print to direct another person's attention to the object

Face: Participant puts the snow goggles print up to their eyes

Experiment: Participant uses the print to experiment with different ways the object could be handled or used

Point artifact: Participant points at the artifact in the vitrine with one or more fingers

Point print: Participant points at the 3D print with one or more fingers

Iconic: Participant enacts an iconic gesture related to the artifact

Assisted Iconic: Participant enacts an iconic gesture with the assistance of a 3D print

Average Gesture per Interview (Emergent Categories)

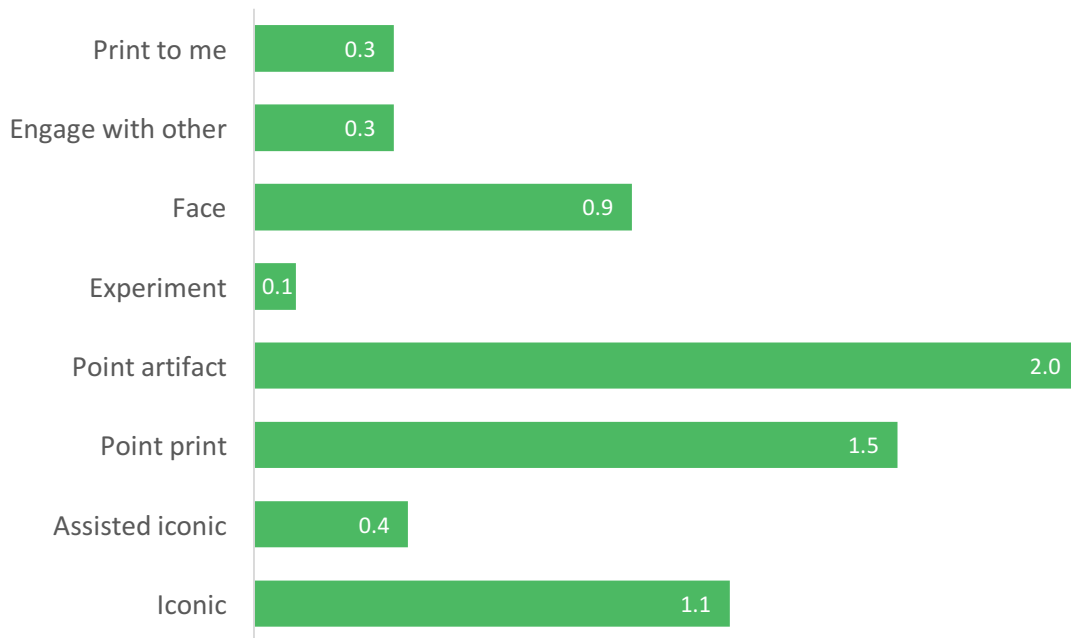


Figure 5, n=29

These gestures all fall into the iconic and deictic gesture categories. Therefore, I combined all the gestures into these categories and split them into whether the participant was referring to the artifact in the vitrine or the 3D print. I combined “showing print to me”, “engaging with another”, and “point print” into the “deictic print” category. I also combined the “experiment”, “face”, and “assisted iconic” categories into the “iconic print” category. I reclassified the “point artifact” category as deictic artifact and reclassified the “iconic” category as “iconic artifact”. There were some instances of outliers in the number of times a person used one of these gestures, but most participants used each 0-4 times per interview.

Number of Gestures by Interview

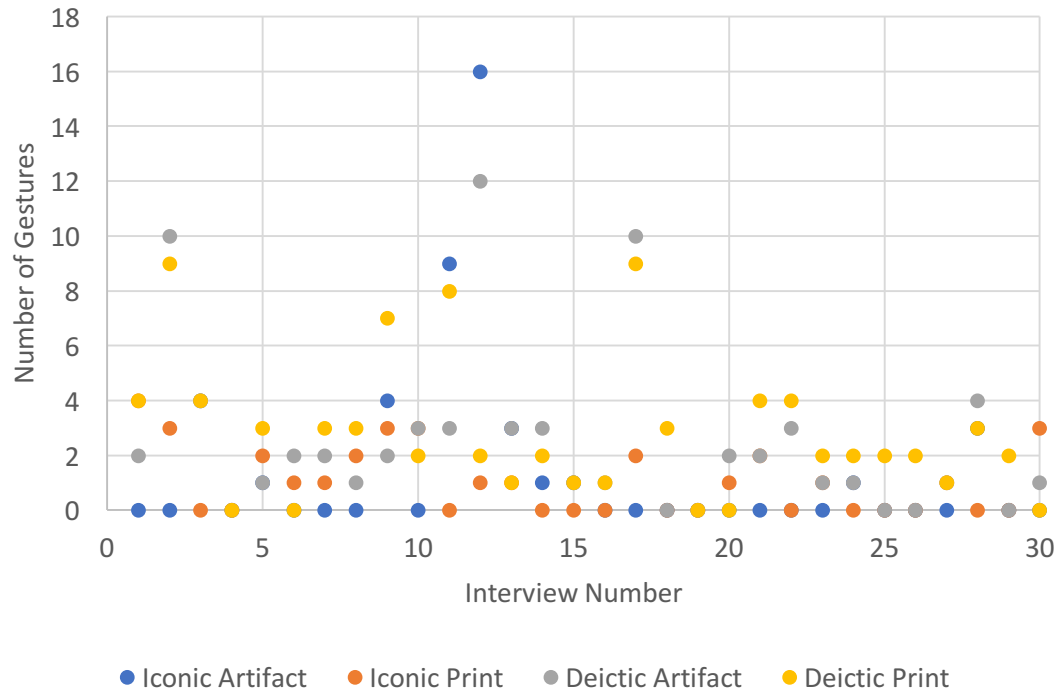


Figure 6, n=30

On average, deictic gestures were more frequently used compared to iconic gestures. Deictic gestures relating to the prints (2.2 per interview) were slightly more common than deictic gestures relating to the artifacts (2.0 per interview). Iconic gestures relating to the artifacts (1.4 per interview) were on average less common than those relating to the prints (1.4 per interview).

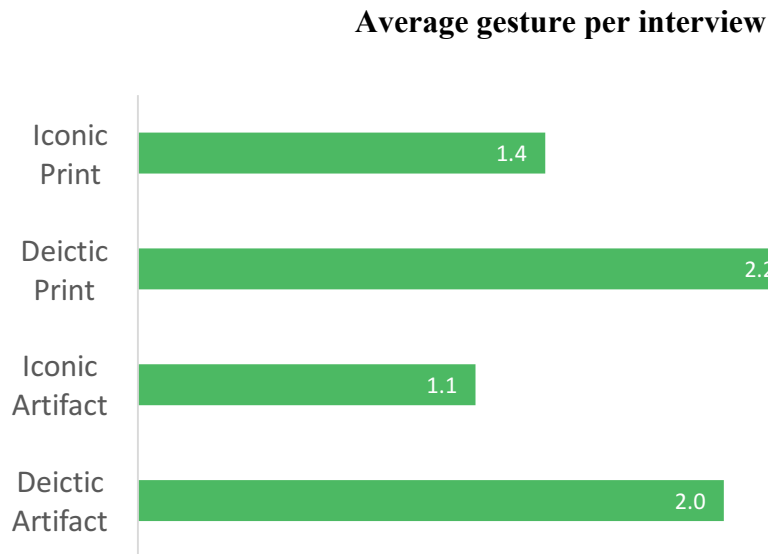


Figure 7

Most gestures in the iconic print category were comprised of the “face gesture”, even though only 27% of participants picked the snow goggles to talk about.

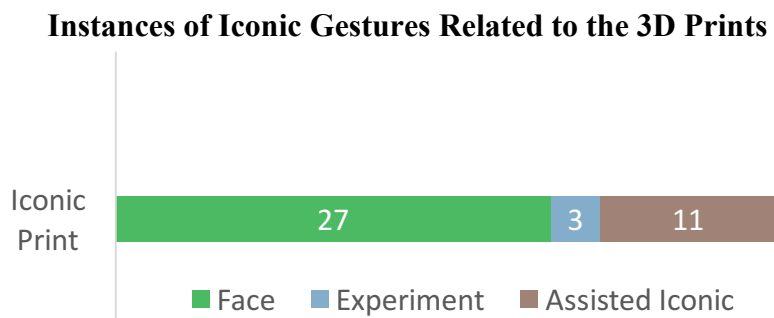


Figure 8

28 participants (93%) used at least one gesture corresponding to a 3D print. Two used no gestures at all. No participants used gestures solely targeted at the artifacts in the vitrine.

Percentage of gestures directed at 3D prints

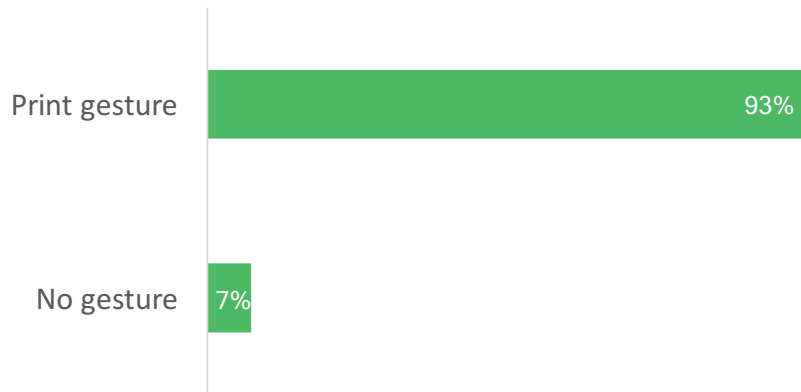


Figure 9, n=30

The participants' reaction to the 3D printed objects was overwhelmingly positive. Twenty-six of the thirty participants viewed the prints as a positive addition to the interview. Three participants had neutral reactions and one person thought the prints took away from the experience.

Reactions to 3D printed artifacts



Figure 10, n=30

Museum Visitor Interactions with 3D Printed Artifacts

The participants had a range of reasons why they thought the prints were a positive, neutral or negative addition. Of the positive responses, twenty-four gave a reason for their reaction. Many people had multiple reasons, and these are counted separately. For a list of example responses for each category, see Appendix A.

-Eight (33%) mentioned that they learn through touch or enjoy touching objects in a museum.

-Seven (29%) mentioned that the prints aided in seeing the object better or allowed them to see the object from a different angle.

-Seven (29%) mentioned that reached a new conclusion by touching or interacting with the prints that they would not have reached otherwise.

-Five (21%) mentioned that they had fun interacting with the prints or they thought that interacting with the prints was a “cool experience”.

-Five (21%) mentioned that they felt the print aided in interacting with the artifact.

-Five (21%) acknowledged the role the 3D print had in preventing people from touching the original and thus aiding in preserving the artifact.

-Four (17%) mentioned that the print increased their interest in the original artifact.

-Four (17%) mentioned that the print gave them a better sense of the shape of the original.

-Two (8%) mentioned that they could connect in some way to the people who originally made or used the artifact.

-One (4%) mentioned the role 3D prints have in assisting those with visual impairments.

-One (4%) mentioned the how holding the print aids in remembering the experience after the museum visit.

-One (4%) mentioned that they thought the 3D print would aid in engaging children.

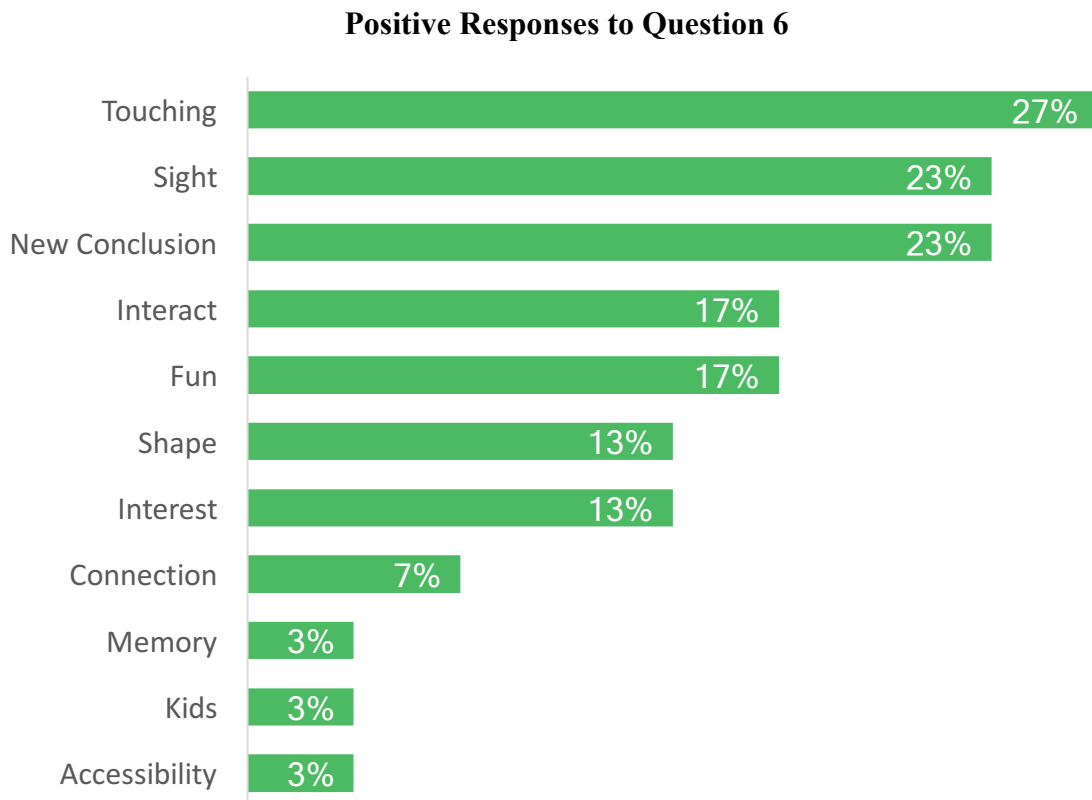


Figure 11, n=24

Of the three participants who had a neutral reaction to the prints, two gave a reason why. Both mentioned that they were visual learners. One mentioned that he recognized the benefits of the 3D prints in preserving the original artifacts and that it might stimulate more inquiry for some people:

“Oh, um, I guess I’m conditioned not to touch things in the museum. So how do you imagine this would be useful, would it be useful for interactions, for visitors? Or also, is it meant to figure out how things were used? In terms of like reducing the wear on the actual. I imagine you would be making this, basically look like these pieces? Um, I think it would allow for kind of, more of a discovery, kind of questioning that happens when

something is behind glass. Like, for example, you want to look inside something or unpacking it because then you have. I think it's useful, but in sort of like the generic form not as interesting or as, um, inviting. Um, in terms of my experience, I think I would be fine with just seeing more than trying to do something with it. I think it would be different if there were something there.”

The one participant who had a negative reaction to the prints explained that she found them distracting:

“Um, well, it's, it's kind of interesting, but it's also distracting to me. Um, you just see this like, really plain white obviously artificial stuff with these very old things. You know, it's probably useful in a certain way, but I find it distracting.”

Discussion and Implications

What kinesthetic responses, if any, are prompted by interacting with the 3D printed objects?

Although most of those interviewed used the prints to help answer my questions, the participants rarely verbalized the evidence they gathered with their sense of touch. Most responses focused on visual attributes, rather than ones focused on shape or texture. This might be because people use a variety of semiotic resources to communicate their thoughts (Streek et al., 2011). Sometimes, communicating a thought verbally is inefficient compared to a gesture or an action. This process can be seen in interview 30:

“I think it would have been like this”
Participant 30 picks up the snow goggles and puts it up to her eyes
“When sleeping. To relax. Yes, that’s what I think. You know, just to keep you peaceful.”

It would have been unnecessary for Participant 30 to describe putting the goggles over her eyes when she could show me instead.

Because the participants often did not verbalize how they came to their conclusions, it is difficult to parse out what information the participant was using to arrive at their conclusion.

Although all of my questions could have been answered by using information drawn from touching the print, most participants explained their guesses by providing visual evidence. For example, Participant 13 used an iconic gesture to explain what she thought the function of the harpoon was, and backed up her guess with a visual argument.

“Well, I guess I would use it for net weaving of some type or maybe, it’s some type of shuttle. Because it looks like a piece of shuttle. Um, making for some sort of textile. Participant 30 waves hand back and forth with finger pinched together in an iconic gesture when she says “net weaving” and “some type of shuttle”.

Participant 13 seems to be drawing from both her visual senses as well as her kinesthetic ones to understand the function of this object. However, she only verbalized what she gathered from sight in her explanation.

Western culture has long privileged sight and hearing over the other senses (Classen, 2012). Museums especially favor visual information over information derived from the other senses. While there has been a push in recent years to incorporate other senses into the museum experience, museums remain places where most information is represented visually (Classen, 2007). Therefore, museum visitors are conditioned to expect a museum experience which is primarily visual in nature. My participants might have felt hesitant in explaining their guesses outside of the visual domain because they felt that the most important information they can learn from a museum is primarily visual in nature.

Moreover, people communicate with an intended interpreter in mind (Enfield, 2011). In the case of my study, I was acting as the interpreter and the participants had to communicate clearly with me. Therefore, they answered my questions in ways they thought I wanted to hear. Several of the participants seemed overly concerned about answering my questions “correctly” and even declined to take a guess because they feared giving the wrong answer. Most participants did not have very much background knowledge about the items on display, so, when

they were compelled to take a guess, they usually talked about aspects they could see. As noted above, my participants did take in more information than just what their eyes could see. So why did they tend to talk about visual information? Like most people in western culture, they might privilege visual information and think it is a more reliable indicator of the “right” answers (Classen, 2007). I think it is more likely that they saw me as an extension of the museum. Through their experiences in these places and their assumptions about what museums are, they might have assumed I was looking for answers which were based off visual evidence.

What kinds of gestures do people use when interacting with 3D printed objects versus objects on display?

Participants tended to use more deictic gestures compared to iconic gestures. This finding matches up with Renner’s (2013) finding that children interacting with a hands-on natural history exhibit tended to use more indexical (pointing) gestures compared to iconic gestures. On average, my participants tended to use more deictic and iconic gestures in relation to the prints versus the artifacts in the vitrine. Differences between artifact iconic gestures versus print iconic gestures and artifact deictic gestures and print gestures, however, were small. Most of the iconic gestures directed at the 3D prints were comprised of people putting the snow goggles up to their eyes. This finding suggests that the snow goggles may elicit more iconic gestures compared to the other 3D prints. Of the participants who used gestures, all of them used at least one gesture directed at a 3D print. The small differences between the artifact and print categories of the iconic and deictic gestures also suggest that the participants did not favor one over the other.

The participants varied in how often they referred to the 3D prints to answer my questions. I think this finding and the nonverbal interactions suggest that the participants found

it useful to interact with the artifact or the print depending on what they were trying to understand about the object. For example, seeing through the slits in the snow goggles allowed the visitor to gain insight on how the goggles block out light. Looking at the artifacts in the vitrine is a better indicator of the material the object was made from because I could not reproduce the original texture or weight of the object. The only question where the majority of participants did not use the 3D print to help them answer a question was question 4, “Who do you think used or made this object?”. This result may be because most people responded to this question by guessing a culture group. For example, Participant 15 explained her answer for question 4 as follows:

“Oh yeah, it’s similar to some of the things you find in some of those Asian stores. So I do see that it is probably from Asia. But I guessed Native American because of the symbols on it. Yeah, and it may have been deer-like animals and stuff. So I guess that’s why I said Native American.”

Because I was not able to reproduce color, the best way for the participants to deduce which cultural style the artifact most closely resembled was to look at the artifact in the vitrine. My participants tended not to guess who made or used the object based on function (a hypothetical answer could be, “I think the goggles were used by a hunter because they need to shade their eyes”) or based on shape (another hypothetical answer could be, “I think someone with small hands made the bowl because it is so little”).

How do museum visitors perceive 3D printed objects in museum environments?

26 participants (87%) reacted positively to having the 3D prints available. 3 (10%) had neutral feelings toward the prints, and 1 (3%) had a negative reaction. These findings suggest that the public is supportive or excited about museums incorporating 3D prints in their galleries. Over a third of the positive responses mentioned that they learn through touch or enjoy touching

objects in a museum. Because museums so often focus on visual displays, these data suggest that there is a sizable group of people who want museums to engage their sense of touch more. 3D prints may also enhance the visual experience. Over a quarter of the positive responses mentioned that the prints allowed the participants to see aspects of the artifact they could not see through the vitrine. 3D prints may also aid education programming. Over a quarter of the participants with positive views said they arrived at a conclusion about the object by interacting with the print which they would not have arrived at by looking at the artifact in the vitrine.

Does the materiality of the object (texture, weight, color) affect participants' interactions or feelings toward the 3D printed object?

Two participants mentioned explicitly that they would prefer the 3D prints to more closely resemble the original artifacts. Several other respondents mentioned that the print did not accurately reproduce some aspect of the original, such as weight, texture, and fine detail. Based on these responses, adding attributes which mimic aspects of the original does seem to be beneficial. My prints were made using the cheapest and most accessible type of 3D printer. It seems that my plain, basic prints still had a positive impact on the people I interviewed. Realism, in this case, seems to be more of a preference, rather than a requirement, for museum visitors. As long as the print is able to reproduce some attribute of the original (in my study it was shape), the 3D prints seem to be useful.

In what ways do 3D printed objects connect present-day people with people from the past?

Empathy in museums is a notoriously tricky subject to measure. A previous paper on 3D printing in museums suggested that prints may be able to deepen museum visitors' emotional connection to objects (Jakobsen, 2016). Emotional experiences are an under-researched, yet vitally important aspect of museum visitor experiences (Smith & Campbell, 2015). Rather than

exhaustively researching the intersection between empathy and 3D printing, I decided to note when I saw evidence of my participants making some sort of indication that they felt connected to the people who originally used or made the artifacts on display. Connection is a small part of empathy, and if it arose spontaneously out of my very limited experiment, it might indicate a way for museums to start to facilitate these experiences for visitors. I defined instances of connection when a participant specifically mentioned something which related themselves directly with a person who used or made the original artifact. Two participants specifically indicated that they felt that the prints increased their sense of connection:

Participant 11: “Especially with this, it gave me more feel for it. I put myself in the, shoes of like, the helmet of the person. Otherwise, if it's just laying there, it's harder to tell.”

Participant 30: “But this, I could see what it would actually go on somebody and how much you could see out and things like that.”

Question 4, “Who do you think used or made this object?”, did not elicit answers which indicated a connection with past people. This finding suggests that museums using 3D prints cannot expect museum visitors to empathize or connect with other people simply by holding a 3D print. However, the presence of these two instances of connection out of thirty interviews might indicate that 3D prints may assist with visitors relating to people who made or used the artifacts. It is also interesting to note that both responses arose out of interactions with the snow goggles. The act of looking out of the snow goggles changes a person’s vision, allowing them to approximate how the original user saw the world. Most visitors, however, may need more interpretation or a different context in order to enter that mindset.

Future Research

Museum Visitor Interactions with 3D Printed Artifacts

Results from my research depends heavily on the context in which the study was conducted. My presence and the questions I asked influenced how the participants interacted with both the print and the artifacts in the vitrine. A future study might expand on my research by analyzing how museum visitors interact with 3D prints in a gallery. While some museums use 3D printing as part of their public programming, more upload scans of items in their collection to publically accessible repositories of 3D models. I have not found any research conducted on how users at home interact with these digital models or the prints that they make. A study could examine the motivations for downloading models from museums and how this changes the user's perceptions of and interactions with the museum.

In addition, my research suggests that museum visitors would like 3D prints which look and feel more realistic. However, no research has been done on how the level of realism affects the visitor's experience. A future study might measure visitor responses to prints with different attributes, such as weight, texture, and visual realism. This study might also examine if there are diminishing returns to adding realism to prints and how museum professionals can balance the benefits and costs to producing these prints.

Chapter 5: Conclusions and Recommendations

The goal of the study was to describe how museum visitors interact with 3D printed artifacts in context with the originals. I conducted thirty interviews at the Burke Museum of Natural History and Culture in Seattle, WA. These interviews were video recorded, and I used emergent coding to analyze both verbal and non-verbal visitor responses. I conducted this study to fill in a gap in regards to how museums can best use 3D printing to engage with museum collections.

Conclusions

Although research participants gathered information based on their sense of touch, they rarely verbalized their thoughts

Non-verbal communication is often more efficient or more precise than verbal communication, and many of my participants communicated ideas by gesture alone. However, when they gave verbal responses to my questions they mainly supported their guesses by drawing on visual evidence. This tactic may be the result of the museum context, where vision is the primary means of communicating information.

The 3D prints were more useful in answering some questions compared to others

Some questions prompted the participants to use the 3D prints more to help answer my questions compared to others. Interacting with the prints seemed to be most useful when understanding the function of the prints. Using the print to understand who used or made the original artifact seemed to be the least useful.

Participants used gesture to understand the objects and engage others

Nearly everyone I interviewed directed at least one gesture at a 3D print, suggesting that the participants found these objects helpful for communication. Deictic gestures allowed the visitor to direct my attention and other visitors to particular aspects of the artifact or the print. Those interviewed also used the prints to assist their iconic gestures, which sometimes compelled them to reach new realizations.

Museum visitors have a positive view of seeing and interacting with 3D prints in a museum setting

The vast majority of people I talked to had a positive view of incorporating 3D prints into the museum setting. The most common responses for why they liked having the prints in the museum included an opportunity for visitors to learn through touch, enhancing visual aspects, and reaching a conclusion that they would not have arrived at if they only looked at the artifacts.

Realism in the 3D prints is desired, but not a necessity

Two people specifically commented that they would enjoy more realistic prints, and several others commented that the print was not able to capture all the attributes of the original. However, the participants still had a very positive view of the prints and used them to aid in their understanding of the artifacts.

More research needs to be done on the connection between 3D prints and empathy

Two participants specifically mentioned that the 3D prints allowed them to connect with people in the past. This data may suggest that there is potential for 3D prints to help in efforts related to empathy, but that museum visitors may need more context or a different setting. Empathy is very difficult to measure, and this question would benefit from a more thorough analysis.

Recommendations and Future Research

My study design was conceived out a limited time frame and budget and would make for a poor gallery installation. Simply touching an object will not provide enough information for a visitor to make sense of what they are interacting with or gain any profound new insights (Renner, 2013). 3D technology in museums should be surrounded by enough context so that the visitor can use a range of resources and senses to engage with museum content. Moreover, I only examined how museum visitors engaged with the final product of the 3D printing process. Neely and Rozner (2015) reported greater program participant satisfaction when they were given the opportunity to contribute to more steps of the 3D printing process. Future studies may look at how museum visitors interact with 3D printing in the context of an exhibit, which would provide a more naturalistic insight on how visitors use 3D technology in the museum.

My research shows that any future studies into 3D printing in museums should take into account gesture and non-verbal action. Audio recordings and surveys do not capture the rich information people express through their bodies.

More integration of 3D printing in the museum might provide an avenue for museums to move away from prioritizing sight over the other senses. However, adults in the museum may need to be encouraged to let go of their reliance on visual information. Further research might examine how adults use their senses in the museum, and if 3D printing can encourage them to use haptic and kinesthetic information when making sense of museum objects.

Although I designed my study to be an interaction between myself and one participant, the people I interviewed often used the prints to engage their friends and their children. This is a result I did not foresee, and consequently I was not able to delve very deep into the social implications of 3D prints. Future research might examine how groups of museum visitors

Museum Visitor Interactions with 3D Printed Artifacts

interact with 3D printing in the museum. Another line of inquiry could be how virtual visitors use, transform, and share 3D models and prints uploaded by museums to 3D digital repositories.

One of my participants mentioned that interacting with touchable objects helps her to remember the objects after she leaves the museum. The role of objects aiding in memory recall is already well established in academic literature (Sutton, 2006). A future study might examine if participating in the creation or printing of 3D models helps people remember museum objects after their visit.

It is my hope that museum professionals will not dismiss 3D technology simply because it seems like a novelty. Incorporating 3D technology requires a shift away from traditional, vision-centered exhibits to a more freeform, sensory, and interactive experience.

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Appendix A: Coding Categories for Question 6

1. Facilitating sight

Example: “I think it was, because then I could see like things I couldn't see unless I could flip it around, especially if there are like, casings, then you can't look at them from different angles, but here you can see like the whole, and then you can guess, like this was used for.”

2. Arriving at a new conclusion

Example: “I wouldn't know what it was unless I could pick it up.”

3. Increasing interest in the artifacts

Example: “Well, it made them more interested than they would have been otherwise. Probably my main reason otherwise I would have just walked by.”

4. Increased interaction or engagement

Example: “Oh yeah! Very, it's much more engaging. I think it allows for people to interact with things more and more.”

5. Get a better sense of the shape or size of the original

Example: “But it's interesting to sort of get a sense of the size.”

6. Helps remembrance

Example: “It helps me to remember because I'm touching it, not just looking at it”

7. Increase accessibility for visually impaired visitors

Example: “I think that's a benefit to a lot of things, especially like, or you have someone who is like, vision impaired. They can still be a part of the museum and get to experience it.”

8. Fun

Example: “That was really fun.”

9. Preservation

Example: “Yes, I think something tangible you can get an idea, something that but sometimes you want to preserve the actual specimen.”

10. Learning through touch or likes touching things

Example: “No, it is because I'm a touchy person, I like to touch things, so I think it's a good idea to have them out here for people to touch since you can't touch the real thing. I just think it's human nature to want to touch things.”

11. Creating a connection

Example: “I put myself in the shoes of like, the helmet of the person. Otherwise, if it's just laying there, it's harder to tell.”

12. Good opportunity for children

Example: “I think so, especially for kids.”

13. Visual Learner

Example: “Um, I'm a visual guy. And so, actually touching stuff. I do it sometimes, but I'm more visual. I like to look at it, think about it. So for me, it's okay, and I was tempted to pick that one up, but uh the display is clear and precise so there's not issue with being able to see.”

14. Prints are distracting

Example: “Um, well, it's, it's kind of interesting, but it's also distracting to me. Um, you just see this like, really plain white obviously artificial stuff with these very old things. You know, it's probably useful in a certain way, but I find it distracting.”

Appendix B: Emergent Gesture Categories

- 1. Show print to me:** Participant directs my attention to the 3D print by bringing it closer to my face
- 2. Engage with another:** Participant uses the print to direct another person's attention to the object
- 3. Face:** Participant puts the snow goggles print up to their eyes
- 4. Experiment:** Participant uses the print to experiment with different ways the object could be handled or used
- 5. Point artifact:** Participant points at the artifact in the vitrine with one or more fingers
- 6. Point print:** Participant points at the 3D print with one or more fingers
- 7. Iconic:** Participant enacts an iconic gesture related to the artifact
- 8. Assisted Iconic:** Participant enacts an iconic gesture with the assistance of a 3D print