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Augmented Reality in the Museum

Creating and Evaluating an AR Mobile Application in an Exhibition

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Abstract

The purpose of this thesis is to map the process of making an AR application using 3D models for a museum, and study visitors' experience of the application and investigate if the application generates a more meaningful experience compared to not using the application. The mix of digital production and empirical study of the created technology is a new way of investigating digital cultural heritage. The research questions include: How can a mobile application using augmented reality be created for a museum? In what way can the application be an example of a polysemic digital knowledgescape? Does the application generate a more meaningful experience of the exhibition?

The augmented reality application was made using different software; the 3D models were made using photogrammetry and the application was made in the program Unity 3D. The application has a three-step information experience: an AR camera mode, object view with a rotate function of the 3D model and a short text, and lastly a link to the object's webpage on the museum online database. The experiences of the visitors were investigated by using two focus group interviews where the first group used the application and the second group didn't use the application. The material thus consists of the application itself and the recorded and transcribed focus group interviews. The study showed that the application was engaging to use and generates a more meaningful learning experience to visitors, especially because of the gamification elements in the application. It is also shown that a fluid experience when using technologies are important for a meaningful experience; if the technology doesn't work well visitors will not use the technology at all. The results also revealed that without the museum building and the exhibition the application wouldn't be meaningful to visitors.

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1. Introduction

Museums are becoming more and more digital. Almost all museums today work with digitizing their collections, using digital tools in exhibitions and being active on social media. Probably the biggest reason for digitizing collections is making the collections more accessible to the public and engage visitors to learn more. Digital tools in exhibitions are used to engage visitors and serve as a complement. A big challenge for museums is studying how the online databases and digital tools in exhibitions actually work and how visitors use and experience them. Digital humanities is an interdisciplinary research field with the closest ties to literature and linguistics, but museology, heritage and other fields are also within the digital humanities. It is important to study how the digital co-relates, affects and is being used within phenomena concerning the humanities.

Museum online collections has been accused of not being user-friendly and engaging to non-specialist users, which result in collections not being accessible although that was the original plan with digitizing.[1] A desirable approach for digital collections and digital tools is that they are designed to be *digital polysemic knowledgescapes*. In other words, they should contain multiple meanings and be easy to use for different users which results in better learning and meaningful experiences. This study is also an example of how a technology can be created and tested while having a digital polysemic approach on each process.

I chose to create and study an application because I'm interested in how digital tools are designed, used and experienced in museums and how they can engage visitors and make their visit more meaningful. I'm also interested in how digital tools can aid in displaying museum objects and collections in new ways. Displaying museum objects as 3D models is a relatively new occurrence and it's important to research how that is experienced by visitors.

1.1 Research Questions, Purpose and Delimitations

The purpose of this thesis is to create and study the experience of a museum application and this will be realized in two steps. The first step consists of creating a museum mobile application using augmented reality with 3D models as well as mapping the process of the work as an "outsider" of the museum. The second step is to investigate visitor's experience of the application and to find out if the application generates a more meaningful experience compared to not using the application. The mix of technical production and empirical

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[1] Fiona Cameron and Sarah Kenderdine, *Theorizing Digital Cultural Heritage: A Critical Discourse*, Media in Transition (Cambridge, Mass. ; London: MIT Press, 2010), chap. Digital Knowledgescapes: Cultural, Theoretical, Practical, and Usage Issues Facing Museum Collection Databases in a Digital Epoch. 173.

investigation of the created technology is key in this project and hints at the essence of digital humanities and interdisciplinarity. The research questions for this thesis are as follows:

- How can a mobile application using augmented reality be created for a museum and what does the process look like?
- Can the application be considered a digital polysemic knowledgescape?
- In what way can the application generate a more meaningful experience of the exhibition?

1.1.1 Delimitations

I made the decision to not focus on more advanced technical issues for this thesis.

1.2 Disposition

This report will be in two parts: the first is about the mobile application and the second one is about the case study. I chose to organize it this way to keep the report clear and easy to read. The first and the last chapters are about the whole project, to set an introduction and an overall conclusion.

1.3 Background and Previous Research

Learning and meaningful experiences in museums have been researched since the introduction of "the new museology" at the end of the 1980's. This term references how museums went from being institutions of education and learning to being more focused on visitors' experience and personal reactions and interactions with exhibitions. Peter Vergo's book *The New Museology* is often viewed as the starting point for this perspective in museology.[2] John H. Falk and Lynn D. Dierking has done significant research on visitors' learning experiences in museums and meaning-making. They focus on questions like why people go to museums, what they do there and how the learning experience can be more rewarding.[3] Studies on the museum visitor experience in Sweden has been conducted by Eva Insulander in her doctoral thesis from 2010. She recorded and filmed visitors in an exhibition and interviewed them afterwards. The results showed how visitors act in exhibitions and

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[2] Peter Vergo, *The New Museology.* (London: Reaktion, 1989), http://ezproxy.ub.gu.se/login?url=http://www.GU.eblib.com/patron/FullRecord.aspx?p=475113.
[3] John H. Falk and Lynn D. Dierking, *The Museum Experience*, annotated edition (Walnut Creek, CA: Routledge, 2011); John H. Falk, *Identity and the Museum Visitor Experience* (Walnut Creek, Calif: Left Coast Press, 2009); John H. Falk, *Learning from Museums: Visitor Experiences and the Making of Meaning*, American Association for State and Local History Book Series (Walnut Creek: AltaMira, 2000).

remember their visit.[4] Research on visitors' experiences of handheld multimedia guides using smartphones has been done by Helen Petrie, Mohd Kamal Othman and Christopher Power. In an article from 2017 they describe a case study of visitors' experiences of a smartphone guide in the Holy Trinity Church in Stratford-upon-Avon (also known as Shakespeare's church). They used a system of scales with factors that visitors responded to, and the results showed that visitors using the smartphone guide had a more positive experience and spent more time in the church.[5]

My study is within the field of digital humanities, which originated in the 1960's and was then called humanities computing. Digital humanities is a subject that focus on the different relations and aspects between the digital and subjects within the humanities. Fiona Cameron and Sarah Kenderdine has edited an extensive anthology theorizing the different aspects of digital cultural heritage.[6] Studies on 3D and AR technologies in museums are still new. An interesting study where a 2D picture and a 3D reconstruction was compared to each other through peoples' experiences of them was conducted by Fabrizio Galeazzi, Paola Di Guiseppantonio Di Franco and Justin L. Matthews in Italy. Their results showed that the different visualizations had different benefits, but the 3D reconstruction generated a better understanding of form and proportions according to the visitors.[7]

2. Making the Application

In this part of the report I will explain the creation process of the prototype mobile application and theoretically discuss it. The application was made to be a supplement to the exhibition Crossroads at the Museum of World Culture in Gothenburg, Sweden. The application was made in collaboration with the museum.

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[4] Eva Insulander, *Tinget, rummet, besökaren: om meningsskapande på museum*, Doktorsavhandlingar från Institutionen för didaktik och pedagogiskt arbete, Stockholms universitet 7 (Stockholm: Institutionen för didaktik och pedagogiskt arbete, Stockholms universitet, 2010).
[5] Helen Petrie, Mohd Kamal Othman, and Christopher Power, "Smartphone Guide Technology in Cultural Spaces: Measuring Visitor Experience with an IPhone Multimedia Guide in Shakespeare's Church," *International Journal of Human–Computer Interaction* 33, no. 12 (December 2, 2017): 973–83, https://doi.org/10.1080/10447318.2017.1304606.
[6] Cameron and Kenderdine, *Theorizing Digital Cultural Heritage*, chap. Digital Knowledgescapes: Cultural, Theoretical, Practical, and Usage Issues Facing Museum Collection Databases in a Digital Epoch.
[7] Fabrizio Galeazzi, Paola Di Giuseppantonio Di Franco, and Justin L. Matthews, "Comparing 2D Pictures with 3D Replicas for the Digital Preservation and Analysis of Tangible Heritage," *Museum Management and Curatorship* 30, no. 5 (2015): 1–22, https://doi.org/10.1080/09647775.2015.1042515.

2.1 Method and Theory

2.1.1 Description of the Application

Before I present the methods used for creating the application prototype, I think it is necessary to describe it. The application uses augmented reality technology to show 3D models of museum objects in the permanent exhibition Crossroads.[8] The objects shown as 3D models have a connection to the exhibition but is currently not on display. The application is making objects in storage accessible to visitors as 3D models. Four objects are used in the application. Augmented reality is a technology that overlays virtual content over the real world, so that both can be experienced at the same time often involving a camera.[9] The augmented reality technology in this application works in using a tablet or smartphone camera with printed targets which are connected to the 3D models.

When the 3D model is shown you can click the model which takes you to the *object view*; a page with a rotatable 3D model and a short text about the object. On this page you can also click an archive button which takes you to the object's online database webpage.[10] The application has an *about page* containing information about used icons and other information that is required. The application also has a *start page* with a basic description of the functions. For a clearer understanding of the application see the photos in appendices.

2.1.2 Method

The methods used to create the application was photography and different software using my own Macbook Air 2015 edition. The first step in creating the application was to make the 3D models and the models of the museum objects were made using the method photogrammetry. Photogrammetry is a term that describes the creation of 3D fields using photography and *remote sensing* to detect, measure and record complex real-world objects or environments.[11] The photogrammetry software Agisoft Metashape Pro (formerly known as Agisoft Photoscan) was used to create the 3D models, and the programs Meshmixer and Autodesk Maya were used to edit the models.

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[8] "Crossroads," accessed April 3, 2019, http://korsvagar1.varldskulturmuseet.se/index.php?
[9] Mark Billinghurst, "Augmented Reality," in *The SAGE Encyclopedia of the Internet*, 3 vols. (Thousand Oaks,: SAGE Publications, Inc., 2018), 35–40, https://doi.org/10.4135/9781473960367.
[10] "Carlotta - Om Carlotta," accessed January 8, 2019, http://collections.smvk.se/carlotta-vkm/web.
[11] Susan Mayhew, "Photogrammetry," in *A Dictionary of Geography* (Oxford University Press, 2015), http://www.oxfordreference.com/view/10.1093/acref/9780199680856.001.0001/acref-9780199680856-e-2357.

The game engine Unity 3D was used to make the application. You don't need advanced programming skills to use Unity, even though some coding in C#* is required. Vuforia Engine[12] was used for the AR function in the application which can be paired with Unity. I will explain the methods in detail in the rest of this chapter.

2.1.3 Theory

To help analyze the application and answer my research questions I will use concepts from digital heritage research. In the chapter "Digital Knowledgescapes: Cultural, Theoretical, Practical, and Usage Issues Facing Museum Collection Databases in a Digital Epoch" in the anthology *Theorizing Digital Cultural Heritage: A Critical Discourse* the authors Fiona Cameron and Helena Robinson write about digital polysemic knowledgescapes. They discuss the challenges of museum digital databases today and how they can be more user friendly, effective and accessible. They start with the theoretical foundations of the museum database and how it has changed through the different epistemologies since museums opened to the public in the late 19th century.[13]

Museum collecting is a knowledge-creating process and not solely about collecting objects. To be able to create polysemic knowledgescapes in museum spaces polysemic collecting is key. The aim in polysemic digital collecting is to "[…] create rich knowledge environments able to describe, explain, and interpret museum collections with reference to different historical, disciplinary, cultural contexts and discourses."[14] Museums have been stuck in traditional documentation practices for a long time because they underpin the culture and activities of the traditional museum. But the Internet and digital technologies are very different media that work in other ways in communication. Internet can potentially be viewed as the ultimate postmodern media in the way information can be shared, organized, manipulated and segmented in multifarious ways. If museums are to remain accessible and inspiring to audiences, new open and polysemic digital collection practices need to be installed.[15]

Museum online databases and websites often don't meet visitors' requirements today. Online databases and museum websites are usually designed to be used by museum professionals; curators, educators and registrars among others. A more visitor-friendly and easy to use interface is necessary if museums want visitors to be engaged to use their online

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[12] "Vuforia - Engine," accessed April 3, 2019, https://engine.vuforia.com/engine.
[13] Cameron and Kenderdine, *Theorizing Digital Cultural Heritage*, chap. Digital Knowledgescapes: Cultural, Theoretical, Practical, and Usage Issues Facing Museum Collection Databases in a Digital Epoch 169-171.
[14] Cameron and Kenderdine, *Theorizing Digital Cultural Heritage*, chap. Digital Knowledgescapes,166.
[15] Cameron and Kenderdine, chap. Digital Knowledgescapes,186-187.
*C# is a programming language developed by Microsoft.

databases. Polysemic digital collecting is when multiple meanings of collections and objects are presented online. Museum objects have multiple contextual possibilities that can be shown in additional multimedia: text-based information, visualizations, maps and so on. The authors propose using links in different ways to convey multiple contexts. They also mention 3D visualizations and VR as good technologies for creating more immersive ways to communicate knowledge. This more complex online service could be considered a digital polysemic knowledgescape. The concept describes the end result of polysemic digital collecting and the opportunities that digital media has compared to the analog. Analog media cannot share and show information in the same multifaceted way as digital communication. I will use the concept of digital polysemic knowledgescapes in this study.[16]

2.2 Implementation Process Description

2.2.1 Preparations

The most important aspect of the preparations for the application was to establish contact with the museum.* The communication with the museum started when I did a test of this project in another course during the fall of 2018. I developed the initial idea for the application during that course and I got in touch with the photographer at the museum who helped me realize this thesis. The collaboration was accepted by the Head of Collections; the first step necessary to get access to the museum objects. The museum is obligated to work with the public and research as a public institution, which was the main reason the collaboration was accepted.

I was put in contact with an antiquarian at the museum storage facility after the project got accepted. The antiquarian was going to help me handling the objects and help with the selection of suitable objects since she had knowledge in ethics, handling and conservational aspects. The preparations also included time management of the whole process.

2.2.2 Choosing Museum Objects

The process started with selecting suitable museum objects for photographing. The application is intended to be an addition to the exhibition Crossroads and I wanted the museum objects to be connected to the different themes in the exhibitions, but not on display currently. The exhibition is about how people of different cultural backgrounds has met in the past and present and how that has affected the world in different ways. The exhibition has seven different themes including Water (water vessels and objects), Pachakuti (South

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[16] Cameron and Kenderdine, chap. Digital Knowledgescapes 173-177.
*I work part-time at the museum which probably helped in establishing contact.

American cultures), Democracies (objects with a connection with perspectives on democracy), Dikenga (cultures from the Congo), Mecca (about hajj), The Silk Roads (about the history of the silk roads) and Borderline (about divided cities in the world).[17] The decision to include objects in storage connected to the exhibition is key in this project. It's an exercise in digital polysemic expression and making museum collections more accessible to visitors. The exhibition is widened and becomes more immersive and interactive when more objects are added as 3D models.

I had already finished one object (the basket) connected to the water theme in the exhibition in the other course I mentioned, so I had a minimum of three more objects to choose. I started searching the online museum database Carlotta for suitable objects. I searched using key words like "Congo", "Peru" and "China" because most of the displayed objects in the exhibition come from those countries. The criteria for the objects were that they had to be suitable for 3D model-making. These criteria include: the objects are solid with no loose pieces that easily moves, the objects don't have too many nooks and crannies which makes the photographing harder, and the objects aren't too shiny which can jeopardize the photo process (reflections can make texturizing the model very challenging). These criteria are for work in photogrammetry and the program Metashape specifically. As with most digital technologies new approaches and solutions will be developed in the future and solve problems like these. This is important and a reason why technologies become dated quickly.

After looking through 100-200 pages with photographed objects in the online database, I chose twelve objects that I found suitable to photograph, a few objects in three different themes in the exhibition, to make the visitors explore more. The exploration aspect of the application is a way to *gamify* the application. Gamification is often used to improve user engagement, flow and learning in non-game contexts, including museums.[18] Video games' relation to digital humanities have been covered in the chapter "New Media and Modeling: Games and the Digital Humanities" in the anthology *A New Companion to Digital Humanities*. Author Steven E. Jones writes about how digital humanities can learn from video games to become more experimental with larger cultural issues since video games are one of the most widely experienced new media today. Not to mention the opportunities in immersive experiences that games can express.

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[17] "Crossroads."

[18] Sebastian Deterding et al., "From Game Design Elements to Gamefulness: Defining 'Gamification,'" in *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments*, MindTrek '11 (New York, NY, USA: ACM, 2011), 13, https://doi.org/10.1145/2181037.2181040.

I sent the selection of museum objects to the antiquarian who investigated questions concerning ethics, sensitivity, provenance and conservation. Some objects had issues with one or more of these questions, in the end we agreed on four final objects: a chair from the Congo region, a table from Papua New Guinea, a figurine from China and a sculpture from Mexico.

One can argue that the technical criteria and museological criteria *chose* the objects, in a Latouresque* way. The first selection of objects was made by me (in choosing the search words) but the rest was done by the criteria themselves. If the criteria had been different, different museum objects would probably have been considered. This shows how powerful and meaningful the different criteria are in making objects accessible to visitors. Most museums are members of the organization ICOM (International Council of Museums) and apply the ICOM Code of Ethics on all of their work.[19] Should the same ethical and conservational regulations be applied to 3D reconstructions of museum objects? Can objects considered sensitive or too fragile be shown as 3D models instead of not being shown at all? This is an important issue due to the way objects are chosen, kept and presented in museums.

2.2.3 Creating the 3D Models

After agreeing on the museum objects, the antiquarian and I decided on two days for photographing. I had access to the photo studio and the museum photographer for help with camera techniques. The object was put on a table in the middle of the studio so I could circle around it with the camera, and two studio lights were used. The lighting solution was not ideal, and it affected the quality of the 3D models. But since the purpose of the models isn't conservation or detailed research, they suffice for this project despite the lower quality. I took about 100 to 200 photos of every object in different angles (lower, straight ahead and from above). One object, the chair from Congo, failed and I had to leave it out of the project.

The photos were imported into the photogrammetry program Metashape after the photographing. Pictures of the work on the models in the different programs are available in appendices. The first step in Metashape is aligning the photos, and most of the time you have to add markers in the photos for them to successfully align. The creation of the dense point cloud can begin after aligning the photos. This took about 20 minutes to a couple of hours depending on the object I was processing. When the point cloud is completed a detailed cleaning process begins with removing faulty data.

I worked with *chunks* to create the 3D model of the dog, one chunk for the body of the dog just standing on its four legs and one for the underside of the dog. You simply separate

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[19] "Standards - ICOM," accessed April 16, 2019, https://icom.museum/en/activities/standards-guidelines/standards/.*I'm referring to the scholar Bruno Latour and the actor-network-theory.

the photos of each area into different chunks (similar to a folder) and do every step on each chunk. In the end the chunks are merged and the data from all sides are visible.

At this point you have the net of points that will create the mesh: the surface of the 3D model. After building the mesh all models were edited in the program Meshmixer. In this program you can manipulate the mesh: flatten it, drag it out and fix holes. After the editing in Meshmixer the models were exported back to Metashape, and the mesh was decimated to 60,000 faces for better handling in Unity. The last step in finishing a model is applying the texture (color). All models have some discoloration mistakes, more time and better lighting would've been needed to create better textures.

Photogrammetry is fragile in how the practical environments greatly affect the outcome. The texture can't be manipulated in any way in Metashape. The practical environment is important to make accurate models and that is probably an issue for most museums. A lot of museums don't have a bigger photo studio and the advanced lights that are needed to make detailed models. The quality can also depend on what the model will be used for: documentation and conservation or experience purposes like an application. The quality of the 3D model has to be simplified first of all to work in the application, so a more detailed model is unnecessary. A more exact model works for documentation and conservation, but a simpler model can be used for visitor experiences in exhibitions successfully. To discuss this, we need to elaborate on what digital heritage really is for.

Neil Silberman discusses what digital heritage really is and should be in his article "What Are Memories Made of? The Untapped Power of Digital Heritage". Silberman wanted to investigate how memory figures in digital heritage. Based on recent neurological research he describes that memories are made of meaning. Remembering is not merely preserving or digitally reconstructing objects but about our experiences of heritage; feelings, facts and sights build our memory of something. Heritage was considered more fixed and unquestionable in the past. Silberman suggests how digital heritage should move forward like this:

> […] I would argue that to become a more effective medium of heritage and collective memory, digital heritage should focus less on authentic-looking visual representations of officialized relics and monuments and much more on widening and deepening the web of stimuli, facts, and emotions that come together—quite independent of the experts—to create powerful new memories in both the human mind and soul.[20]

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[20] Neil Silberman, "What Are Memories Made of? The Untapped Power of Digital Heritage," 6, accessed May 20, 2019,
https://www.academia.edu/21502567/What_Are_Memories_Made_of_The_Untapped_Power_of_Digital_Heritage.

To move forward we perhaps need to move away from our obsession with exactness and start understanding how meaningful experiences of museum visits are made. Our understanding of a satisfactory museum visit and how memories are made needs to change.

2.2.4 Creating the Application

The application was made in the program Unity 3D. The general design and different pages of the application had already been designed when I started the project. I needed to add the three additional 3D models in the AR camera mode and create three new pages for each object. I wanted the design of the application to be as simple as possible, so it would be user friendly for most people. The visitor will experience the object in three steps: in augmented reality, as a rotatable 3D model with a short description and on the museum online database.

Why was augmented reality chosen as the technology for this application and project? Augmented reality can like its close relative virtual reality immerse the user in a digital environment where information is responsive to the user's action. AR has been identified as one of the emerging technologies most likely to transform learning in both informal and formal settings.[21] AR has great potential in education and can enhance learning, especially when using a mobile device (the AR feature becomes portable and thus more personalized). The interactivity, connectivity, context sensitivity and individualization make the experience more meaningful.[22] AR is believed to have great value in situated learning, discovery-based learning and experiential learning, these concepts maintain that learning is grounded in action and dependent on the learner's physical, social and psychological context. There is also evidence that AR applications can motivate, engage and support collaboration and conceptual understanding among learners. A disadvantage of AR is cognitive overload; when there's too much information for the user to digest. Keeping the design simple is important to reduce the risk of information overload.[23]

Perhaps the most important thing of the functionality of the application was to find out how the AR targets would work in the exhibition; mainly if they would be fastened or not. The targets used were simple pictures of symbols (they are available in appendices). During a meeting with an exhibition producer at the museum it was agreed that loose targets would work best. Movable targets would be more interactive and make it easier to explore the object from all sides. 3D models are best experienced from all sides and angles, so a movable target

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[21] Camillia Matuk, "The Learning Affordances of Augmented Reality for Museum Exhibits on Human Health," *Museums & Social Issues* 11, no. 1 (January 2, 2016): 73–74, https://doi.org/10.1080/15596893.2016.1142815.
[22] Danakorn Nincarean et al., "Mobile Augmented Reality: The Potential for Education," *Procedia - Social and Behavioral Sciences* 103, no. C (2013): 662–63, https://doi.org/10.1016/j.sbspro.2013.10.385.
[23] Matuk, "The Learning Affordances of Augmented Reality for Museum Exhibits on Human Health," 77–78.

was preferable in that regard as well. A portable target would also encourage interactivity with the 3D model if there is a group visiting the exhibition. Visitors can explore and play around with the objects more easily. The target pictures were printed and glued to a plywood circle of about 24 cm in diameter. This made the targets clearly visible and not so flimsy to handle.

The target for the basket was placed in the water section of the exhibition and printed with the blue color of the theme, the target for the dog was placed in the Pachakuti area of the exhibition and printed with the red color of that theme, the target for the crocodile table was placed in the democracies section and printed with the purple color of that theme, and the target for the figurine was placed in the silk roads section and printed with the associated green color. This would probably make it easier for visitors to recognize which area the target was associated with if it was placed in another area.

The 3D models are not true to size because it wouldn't be ideal for the AR experience. The models couldn't be too big so the camera had to be too far away for the target, and not too small so interactivity would be limited. The application was built to an iPad using Xcode. The application will be best experienced on a bigger screen so that you can clearly see the 3D models.

2.2.5 Technical Problem Solving

Smaller problems with the application occurred during the whole process but the biggest problem occurred when I was placing the models in the object view in the application (where you can rotate the models). The models wouldn't have the right pivot, so they rotated off screen and in the wrong way. This problem was fixed in Autodesk Maya by using the tool *Locator* where the pivot could be placed in the middle of the object. When solving this I could also see that the 3D models were unnecessarily big in size, so I reduced the size a bit which improved the look and function of the models.

2.2.6 The Application as a Digital Polysemic Knowledgescape

As mentioned in the theory section Cameron and Robinson write about the lacking user experience of museum online collections. They focus on usability for general visitors and the importance of expressing multiple meanings of museum objects and exhibitions.[24] How does the application relate to a digital polysemic knowledgescape?

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[24] Cameron and Kenderdine, *Theorizing Digital Cultural Heritage*, chap. Digital Knowledgescapes. 173

Because of the *three-step experience* in the application the user can choose what kind of experience suits them: just exploring the object in AR mode, discover short facts and be able to rotate the object in the object view mode or go to the online database where detailed information about the object can be found. The user has to find the targets in the exhibition and experience each step to reach the next one, making the application explorative. The exploration is a way to make an online database more user-friendly and engaging. The three steps can also constitute different meanings of the objects; as a 3D model to explore freely, a 3D model with a short text, and at last in the online database. The three steps generate different narratives about the objects.

Cameron and Robinson writes positively about the use of AR and VR in museum education: "Virtual and Augmented Reality technologies were also identified as having the potential to deliver detailed, dynamic, immersive experiences in tandem with objects and information in fulfilling learning objectives."[25] They continue mentioning the learning potential of 3D simulations of objects and the ability for the user to freely manipulate and rotate objects. 3D models and environments have the potential to create a contextual ambience for collections and place different objects in spatial relationships. Inspiration from, and use of, computer games is also mentioned as a good way of engaging users and make them choose a specific object or exhibition narrative.[26]

2.3 Results

I have described how an AR application can be created for a museum and what the process was like. If the application can be considered a digital polysemic knowledgescape and if so in what ways has also been discussed.

The process of making the application can be divided in three stages: planning, making the 3D models and making the application. The planning consisted of crucial events like establishing contact with the museum and getting my project approved. Making the 3D models took the largest amount of time consisting of the steps: selecting objects, photographing objects and processing the models. The last stage, making the application, consisted of creating design, scenes, scripts and incorporating the augmented reality tool with adding the 3D models and lastly building the application to an iPad. The most challenging task making the application was making the 3D models. Learning what generally is best for making a photogrammetry model is easy but unforeseeable problems always occur for

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[25] Cameron and Kenderine, chap. Digital Knowledgescapes. 176
[26] Ibid.

beginners. The lighting and how the photo studio is used are factors that impact the end result enormously.

The application can be considered polysemic digitally in the use of 3D models in augmented reality which results in immersive experiences. This will be covered in greater lengths in the next section where the application has been tested and discussed by visitors. But in a production perspective the application can be considered polysemic in the augmented reality and three step experience. Visitors gain new meanings of museum objects when they are presented as 3D models; visitors can freely manipulate and explore the objects in an entirely new way compared to experiencing them looking into a cabinet. This makes the creation of new narratives possible.

3. Case Study

It is important and necessary to evaluate digital technologies that people are supposed to use. I saw it as a natural part of this thesis to include a qualitative study of the application. The study had to be small because of the time limit of the project, but also smaller studies can be helpful and show aspects of human experiences. This is a test of the application "in the wild", in the exhibition where it was intended to be used.

3.1 Method and Theory

I used focus groups to answer my research questions concerning the experience of the application and the 3D models. Focus group interviews are a good method for talking to a group of people about a specific subject, rather than group interviews which consists of more direct questions. By using focus groups, the interviewer can easily learn about people's stories and values since the conversation is more natural.[27]

To differentiate the experiences a regular visitor would have in the exhibition I had one focus group use the application and the other group not using it. Both groups' stories about the exhibition experience were then analyzed. The group using the application explored the exhibition first and had a conversation about their experience afterwards. To make this work I wanted to have smaller groups: mini focus groups of about four to five people. The smaller group size made it easier for the participants to share the iPad and the conversation was more informal.

I decided to have the focus group conversation at the museum because it was most relevant. I had a time limit of one hour for the exhibition visit and conversation, two hours

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[27] Bente Halkier, *Fokusgrupper*, 1. uppl. (Malmö: Liber, 2010), 7–8.

total. To find participants I used university student networks on Facebook. The majority of the participants were interested in museums and history in different ways and this common interest made the conversation easygoing. The only pre-requisite I had for the participants was that they had to be familiar with smart devices. The participants were 20-30 years old. The results of the case study might have turned out differently with other focus group participants with a lesser interest in museums. The participants knew that they were going to visit an exhibition and that my project was about digital tools in museums before experiencing the exhibition with or without the application.

To distinguish the participants' experiences in the exhibition I used the factors used in the article "Smartphone Guide Technology in Cultural Spaces: Measuring Visitor Experience with an iPhone Multimedia Guide in Shakespeare's Church" as a base for the conversation. Petrie et al. used what they called Museum Experience Scale (MES) and Multimedia Guide Scale (MMGS) and combined those to create a unique Church Experience Scale. The factors included *Engagement*, *Knowledge/Learning*, *Meaningful Experiences*, *Emotional Connection*, *User Experience* and *Quality of Use/Interaction*.[28] I used the factors as a base because they cover all aspects of experiencing an exhibition and its digital tools.

For structuring the focus group interview I used the sequential funnel model.[29] The conversation started with a broad introductory question and became more focused on details in the end. I had three main questions in my interview guide: Can you tell us about a good museum experience you've had? Why was it good? What do you think of digital tools in exhibitions? Are they good or bad? Why/why not? How did you experience the information screens in Crossroads?/How did you experience the application? For the last two questions I always had the different factors in mind so that everything I wanted them to discuss was covered.

It's important to have a good introduction when working with focus group works, so the participants feel safe and can to talk freely about the subject. My introduction consisted of meeting the participants in the lobby of the museum, walking up to the exhibition and have a small presentation of my project. I waited in a meeting room downstairs while the participants explored the exhibition and the digital tools. I didn't want the participants to feel observed or pressured in any way. The focus group conversations were recorded to keep the data as accurate as possible. The names of the participants in this report aren't their real names.

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[28] Petrie, Othman, and Power, "Smartphone Guide Technology in Cultural Spaces," 974–75.
[29] Halkier, *Fokusgrupper*, 39.

3.2 Material

The material used in the case study is the recorded focus group conversations and a rough transcription of the recorded material. The two recordings are 55 minutes and 50 minutes long and the transcribed documents generated ten pages in total. Transcribing can be done in many different ways. If you have a perspective where words and the way of speaking is important a more detailed transcription will be made. I have no need to focus on detailed parts of my participants language, so my transcriptions are not that detailed. I focused on the content of what my participants was describing and included what everybody was saying but not every word or pause. I cut out irrelevant parts and excessive or colloquial words. The transcribed material shows the conversation in text which makes it easier to study. I have the transcribed material and recordings on my computer for review.

3.3 Discussion

I will now present and analyze the discussions from the focus groups. This is not about the experience itself but the discussion about their experience. The two focus groups interviews will be presented separately and then compared.

3.3.1 Focus Group 1 (Using the Application)

After visiting the exhibition for an hour, the introductory question for the focus group was to talk about a good museum experience, and all four participants had to share one experience. The participants agreed on enjoying immersive exhibitions that are telling stories. Exhibitions where digital technologies were used in an innovative way and the authenticity of the museum objects were prioritized was also mentioned as good. Vera talked about her visit to Moesgaard Museum in Denmark: "There was this Genghis Khan exhibition, where you sat in a ring with headphones on and there was a projector above showing images in the middle on a podium, and you could hear his [Genghis Khan's] voice telling stories. It felt alive." Vera is talking about an immersive experience in the exhibition she visited.

The importance of immersive experiences in museums has been mentioned before in this report, and the focus group confirmed that importance. The term infotainment, or edutainment, has become common in the museum world and visitors expect to experience edutainment at museums for more engaging learning experiences. Immersive technologies satisfy the cognitive, emotional, recreational and functional experience of seeing.[30] In other

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[30] Filomena Izzo, Domenico Graziano, and Mario Mustilli, "New Procedures in the Museums: The Communication Through Immersive Technologies," *International Business Research* 11, no. 6 (2018): 83–84, https://doi.org/10.5539/ibr.v11n6p83.

words are immersive technologies making learning more fun which increases the likeliness of the visitor learning even more. Immersive experiences feed the natural curiosity of human beings. The satisfaction aspect is covered in the article "New Procedures in the Museums: The Communication Through Immersive Technologies". The article is about a study done at a museum in Italy where a Virtual Reality movie was incorporated in an existing exhibition. A survey was distributed to evaluate satisfaction and the results showed a good level of general satisfaction with the VR application and that the curiosity of further information was the main reason visitors used the application.[31]

The focus group participants agreed on digital technologies as a good complement to exhibitions, especially in showing context. They also discussed how digital technologies can help people that are not that interested to have a better experience. They explained that digital technologies can make the learning fun and easy compared to reading text panels. Their concluded thought on the matter was that digital technologies make museums more accessible. The participants are initially confirming what AR and learning research has shown many years: that learning experiences become more successful when AR is used well.

3.3.2 Experiencing the Application

The majority of the participants talked about how fun it was using the application. They especially focused on the treasure hunt aspect and that the straightforward instructions made it easy to use. Hanna explains it like this: "Some objects were not numbered on the screens, it was a lot more fun to just find the symbol, find the object, find the facts. I liked that, I liked the easy access." Hanna is pinpointing the *three-step experience* around the objects in the application. She also mentions that the existing screens in the exhibition wasn't satisfactory and she couldn't find certain objects. The application was more accessible and fun to use in her opinion.

3.3.3 Learning

The focus group participants talked about missing context in the exhibition overall, and everyone was annoyed by that. The exhibition has text panels and digital screens with additional information, but the focus group wasn't satisfied with the information.

Everyone in the group mentioned that they liked the ability to choose how much they wanted to learn about the objects in the application. Katarina mentioned that she wanted even

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[31] Izzo, Graziano, and Mustilli, 85.

less text in the object view, stating she wouldn't read it. Vera however missed basic facts like place of origin, date, artist and material, she wanted those facts listed. Proportions was another factor that everyone was missing in the AR camera mode and 3D model presentation, it was hard for them to understand the size of the objects. Learning about the objects was a bit different depending on which object it was, Hanna: "The basket spoke for itself, for the dog you had to click one step to get the context and read." The original context of the basket is shown with animation in the AR camera mode. Water, stones and steam was added to the basket to show how it was originally used for cooking. This appeared to be very successful, the focus group talked a lot about the basket and stated it was their favorite object.

When the participants concluded that the basket "spoke for itself" it shows how the object has its own identity and "dimension" as well as multiple meanings. The target of the basket was placed in the water theme of the exhibition. The visitor is therefore already in a context of water and stories about water in different cultures. When finding the target, the visitor experiences the 3D model with animated water, steam and stones in the basket, making it an immersive experience. With just one step the visitor has reached this experience. With the other two remaining steps, the object view and the online database, even more context can be reached. But it wasn't really needed according to the focus group, the context only needed to be shown visually, without text.

When discussing the basket, the participants also talked about authenticity. Authenticity was very important to them, and the basket was an example of how authenticity can be digitally communicated well in their opinion.

3.3.4 Meaningful Experience and Emotional Connections

It is hard to discern what a meaningful experience is. However, I consider a meaningful experience by how graphically and descriptive the participants discuss their experience. All participants talked about how the application was fun, easy to use and that the learning experience was enjoyable. Those factors matter in a meaningful experience. The discussion on how uninterested visitors can have a better experience with an application is relevant as well. But one of the participants also stated that the application is helpful and meaningful to frequent museum-goers too. Using the application can open up other conversations for the more interested visitor, said Jonathan. The rest of the focus group agreed on this. When a new narrative or understanding is taking place in an exhibition it could be referred to as a digital polysemic knowledgescape: multiple meanings form in the interaction with a digital device and the people you use it with.

The participants in the focus group used quite descriptive language when talking about the 3D models. One participant talked about the dog as "the *fat* dog", emphasizing the volume of the dog. This is an example of how an emotive connection can be formed to an object when it is displayed as a 3D model.

The focus group also talked about how meaningful the museum is as a place. No one wanted to be able to display the 3D models at home. The application has to be used at the site, otherwise authenticity and relevance are not present at the same level, one participant said. Museums has been described as *temples* for a long time in museology. This refers to how museums in the beginning were elitist institutions sought out to educate the working class, for instance. The structure of museums resembled temples: large looming structures to be respected.[32] This view is still apparent although the new museology perspective is about changing to a more visitor-friendly and engaging museum. The participants in the focus group might not see museums as temples but nevertheless as meaningful places. Digital displays can't replace actual exhibitions at museums, the site is still important for visitors.

3.3.5 User Experience

User experience is an important factor in discussing an application. Apart from stating that the application was straightforward and easy to use the participants enjoyed the gamification element of the application. The "treasure hunt" made finding the 3D models and facts engaging.

Katarina talked about the technological novelty using the application: "If I was a regular visitor, I think what I would enjoy most is the technological novelty, not the content itself. That I can actually use AR in the museum and do something new. It wouldn't be as fun and interactive if it was a video with the information or so." For Katarina, the experience with AR within the museum was new, and that was most meaningful to her. The content is taking the back seat and the technology is forming a new experience. This can be an example of what visitors expect from museums today, coming back to Cameron and Robinson's chapter about different users of museum online collections and how to accommodate users. The quote from Katarina also tells us how immersive experiences can improve the experience and engage visitors to act and therefore learn more. Engagement, user experience and learning are linked together for creating a meaningful experience.

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[32] Tony Bennett, *The Birth of the Museum: History, Theory, Politics*, Culture (London) (London ; New York: Routledge, 1995); Eilean Hooper-Greenhill, *Museums and the Shaping of Knowledge*, The Heritage (London: Routledge, 1992); Vergo, *The New Museology*.

3.3.6 Experiencing 3D Models Compared to Displayed Objects

The discussion on how the experience of the 3D models was compared to the displayed museum objects was mostly about how 3D models are representations of objects, Jonathan: "The object might be on the surface similar but it's not, it's a translation of the physical to the digital. It's a separate object. There has to be an element of understanding that. This is not the object, it is a translation of it." Jonathan states the importance of pronouncing that 3D models of museum objects are not the objects themselves. It is also important that expectations of users match what they are about to experience. Other participants mentioned that they couldn't tell the objects were old in the same way when experiencing the 3D models. The matte finish and nature of photogrammetry does not render issues like that perfectly.

Technical issues do matter in how the experience turns out for the visitor. The focus group also talked about the color of the objects being a bit different from the photos on the museum online database. They were comparing the two media, which led to different understandings of the objects. The main concern they had was: which rendering is most authentic? This can connect to the discussion above about authenticity and the role that digital heritage can or should take in the future.

3.3.7 Focus Group 2 (Not Using the Application)

The second focus group visited the exhibition for about 50 minutes, and they were encouraged to use the digital screens. The group consisted of students Johan, Anna and Kim. A photo of one of the digital screens in the exhibition is available in appendices (fig. 15). In this group the participants discussed interactivity as the main reason for a good museum experience. Anna said: "I'm always a hundred percent more excited if I see a button!", she states how buttons and other interactive elements in exhibitions make you want to explore. Interactivity makes you act, which matter in how the experience turns out. Texts and lengths of texts were also discussed early in the interview, the participants talked about how long texts are even discouraging them from reading at all. Shorter texts in the exhibition, with an option to read longer texts, was desirable.

When discussing the experience of the digital screens the group started out with covering ergonomics and how the screens were placed. They thought the screens were placed a bit too low, so you had to hunch uncomfortably to use them. The specific placement in height is due to accessibility for people in wheelchairs, which is worth mentioning. The placement of the screens felt strategic to all participants.

3.3.8 Engagement and Experiencing the Exhibition

Everyone in the group agreed on the screens being undynamic and not easy to use. The touch function on the screens wasn't great and it was sometimes hard to get to the page you wanted, or the touch function didn't respond at all. Touch buttons were described as too small which was annoying to the participants. However, the participants thought the screens were easy to find and didn't disturb the overall "flow" of the exhibition. One participant mentioned it wasn't as fun using a screen if someone else had just used it. The screens don't circle back to the "homepage" right away, so a random page can be shown instead of the start page. The other two participants agreed on this. A clean slate when starting to use the screens was desirable for not disturbing one's own plan with using it. This is a clear indication that the screens can't be considered immersive. The feeling of being immersed into something, to be completely interested and in what could be called a digital "flow", does not appear to be present when using the screens.

The screens were not experienced as engaging and this could annoy the participants so much that they ended up not bothering at all with the screens, thus missing information. This can be linked to digital polysemic knowledgescapes and how users' needs are not being met, or that the interface is not meant for a specific user. Cameron and Robinson write about non-specialist users of museum websites and online collections. Since a wide variety of people are accessing the collection many different skills are needed, for example a simple word search function, more advanced tools for the initiated and other complex media to cater learning and entertainment needs. Their research suggests that users value free-choice learning and would access online collections for building on their knowledge as a form of entertainment and planning museum visits. Users prefer a more fluid, formable structure and unique digital information tools that allow the creation of multiple narratives around collections.[33] A more fluid, malleable information structure, or just a better touch screen function, could've probably increased their engagement. This is relevant for all digital technologies.

3.3.9 Learning

The engagement when using the screens in the exhibition is closely linked with the learning experience. The focus group participants talked about the screens not being engaging enough for them to learn as much as they wanted to. The screens should be marketed more to appear more interesting. Kim put it this way: "They should market them more or have better design. The thing with the crocodiles was super interesting but I found that context by accident just

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[33] Cameron and Kenderdine, *Theorizing Digital Cultural Heritage*, chap. Digital Knowledgescapes. 177-178.

clicking randomly. It should be more like: do you want to read about the meaning of this in Papua New Guinea? So you get interested and want to read more." Kim is referring to the democracies area with objects from Papua New Guinea. She is identifying that the screens aren't fun to start using. She describes how she randomly accessed interesting information that she found useful and meaningful. The other participants agreed on this and one of them suggested having highlighted facts for easier access; this could be a bigger button on the screen, or a pop-up function.

A type of guidance towards interesting facts could be a good way for visitors to reach the context they're looking for. Yet again it seems fluidity is showing its importance and value for visitors. Gamification could be used here as well in order to engage visitors. Game-like design could be added to the screens as well. New information about the objects was described as the most fun by one participant. The learning experience would perhaps be more satisfactory if that need for guidance to new information was catered to.

3.3.10 Meaningful Experience, Emotions, and User Experience

The lack of user-friendly screens didn't make the participants engaged to use the screens much. At the end they were fed up with them and experienced the exhibition without the screens. But when information isn't reached you only experience "half" the exhibition, as Johan in the group put it. You don't experience the exhibition as was intended, he explained, and that is not optimal for the experience. Johan: "It is important. The information is there for you. You get annoyed when the exhibition doesn't meet your needs.". They also agreed on that the objects from Papua New Guinea became more interesting when they read about them on the screens. Reading about the objects thus created a deeper narrative.

Johan concluded that all in all the screens weren't user-friendly. They mentioned "tech rage" in relation to this, a negative feeling one can get when technology isn't working well. The exhibition was also harder to navigate when the screens didn't show the right area at the default page, said two participants. A fluidity of the interface is expected from the users, and meeting those needs are important.

3.3.11 Comparing the Two Focus Groups

The two focus group interviews were quite different. The first group, the one using the application, focused more on the experience of the 3D models and the second group talked more about technical issues. The first focus group considered the application easy to use, fun and that it generated a meaningful learning experience. The second group described the exhibition screens as not user-friendly, which resulted in them not learning as much as they

hoped for. Since AR is considered a more immersive experience, this could be a statement on how successful immersive experiences are in education. The participants were also very aware of user-friendliness as a factor concerning the mobile devices which influenced their experience positively or negatively.

Not reaching information and the frustration accompanied with that was something both groups discussed. The first group was disappointed in the exhibition for not showing enough information, but also stating that too much text is not desirable, causing information overload. But they were satisfied with the three information steps in the application. The second group was concerned with how they ended up just experiencing "half" the exhibition after being annoyed by the touch screens (and not using them). The challenge is to not have too much text, but still be able to communicate with visitors that there is more information available. The problem of people not learning as much as they want to in exhibitions can be solved by digital technologies using gamification. Gamification will engage visitors to use the technologies and reaching more layers of information. Using game-like elements in education has proven to be successful, and museums shouldn't be any different.[34]

The importance of how different technologies are integrated in exhibitions was also something the focus groups acknowledged. The AR targets of the application was placed to still encourage the visitors to walk around in the exhibition. This was mentioned as a positive thing by the participants in the first focus group. The placements of the screens and how interesting they appeared was discussed in the second group. The placements of both the AR targets and the screens were quite similar, one in each theme in the exhibition. The targets were quite engaging themselves since they were incorporated in the application in a treasure hunt fashion. The screens could be made to look more interesting, according to the second focus group. This can be an indication of how the technology isn't incorporated into the exhibition well enough for the visitors to naturally use them or want to use them.

4. Conclusion

Museums are built around collections and in order to be relevant they must find ways to open up collections to the public. Research on digital technologies in heritage and cultural institutions is important as these technologies become more common. Studies on how online museum collections function and are used by visitors are relevant as most institutions have digitized their collections. The perhaps biggest question is how different digital media can be

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[34] Seth Giddings, "SimKnowledge: What Museums Can Learn from Video Games," in *The International Handbooks of Museum Studies* (Wiley Blackwell, 2015), 145–64, https://doi.org/10.1002/9781118829059.wbihms307.

used to present collections in a way that engages the visitor and still upholds context, authenticity and conservational aspects. This study is an example on how something can be created digitally and tested by users in the same research project. Showing museums that this can be done with limited programming and photographing skills can hopefully encourage institutions to start creating.

In this report I have presented the process of making an augmented reality application for an exhibition with limited resources. AR and VR are both technologies that render immersive experiences for users, and this is beneficial in learning. AR can also be used to enhance or expose multiple contexts surrounding museum objects, making an exhibition more polysemic.

The project continued with a case study when the application was done. Focus group interviews was chosen as the method for the case study. Two focus group interviews took place, one group used the application and the other didn't. An interview guide was used for both groups with three questions about their experience of the exhibition and its digital tools. Factors from MES (Museum Experience Scale) and MMGS (Multimedia Guide Scale) was used to analyze the discussion of the experience and understand how meaningful the technologies were to the users.[35]

The participants in the focus group using the application liked the three information steps for different narratives. The group using the screens in the exhibition was satisfied but found the screens not user-friendly and annoying at times, which withheld them from reaching context that they initially wanted to explore. The group using the screens talked more technically about their experience and the group using the application talked more vividly about the 3D models and objects. This is an example of how 3D models make objects more accessible and "alive" to visitors. The size of the objects displayed as 3D models was hard to understand for the focus group participants, to reassure the right size is mediated a static, universal object could perhaps be added to the AR camera mode and object view. The object should be something that people can relate to and preferably something with relevance to the situation. An apple is relatable, not perhaps not suitable for the exhibition.

It was apparent that the 3D model of the basket in the application was most successful according to the first focus group. With the animation added to the basket the original use of it came alive. Enhancing the context was found to be most successful comparing to the other 3D models. This shows that certain objects are rendered better as 3D models and how context can be added differently results in an immersive experience of the objects. The immersive understanding leads to better learning experiences for the users. Reaching facts easily with

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[35] Petrie, Othman, and Power, "Smartphone Guide Technology in Cultural Spaces."

digital technologies in the exhibition turned out to be one of the most important factors for a satisfactory experience.

The study also showed how important the museum as a site is to visitors. The participants in the first focus group agreed on the importance of the physical exhibition and museum as a place that symbolized authenticity. According to them the objects would become irrelevant without the museum. Museums can't be replaced by applications in empty spaces, digital technologies should work with the museum site and accommodate the collection in making it more interesting to the visitors. In the end this would make the museum more accessible and interesting for more people.

User experience, engagement and learning are all linked in making an application meaningful to use. Engagement is important for making the users want to use the application and feel engaged to know more. If user experience is bad the user will probably not be engaged to use the application and might even have a negative emotional response. If expectations in engagement and user experience are not met the learning experience will suffer. If the application creates an immersive experience, the learning will be more meaningful.

4.1 Key Findings

This is a summary of the key findings presented with the research questions.

- How can a mobile application using augmented reality be created for a museum and what does the process look like?

A detailed presentation of the process creating an application for a museum has been discussed in this thesis.

- Can the application be an example of a digital polysemic digital knowledgescape?

The application can be viewed as a digital polysemic knowledgescape in the *three-step experience* system and use of augmented reality according to the focus group interviews and the analysis of the application. The three steps and use of augmented reality make new narratives and contextualizations in the exhibition possible.

- In what way can the application generate a more meaningful experience of the exhibition?

The application generated a more meaningful experience because it was engaging to use and was an enjoyable user and learning experience according to the first focus group. The screens in the exhibition weren't dynamic or user friendly according to the second focus group, technical difficulties negatively impacted their exhibition experience. The three factors user experience, engagement and learning are linked and crucial for meaningful experiences of mobile applications. The relationship between the immersive technology (augmented reality) and the three factors resulted in a more meaningful experience.

4.2 Further Research

Further research on the topic of digital heritage should be done concerning how visitors use and experience technologies in exhibitions. Erkki Huhtamo has written an article about "exhibition anthropology", an approach to investigating how visitors navigate through the rules and regulations of museum exhibitions. Huhtamo's approach can be used to investigate the relationship between visitors and exhibition technologies.[36] More research including creation of a technology and a test of that particular technology will hopefully be administered in the future. Nancy Proctor investigates models for understanding museums in the multiplatform environment that is present today and suggests that the relationship between museums and global audiences should evolve to reflect the distributed network structure of the Internet itself.[37] A big challenge for digital heritage studies is to investigate how mobile applications can be more sustainable in the ever-changing nature of new technologies. Research on this is valuable for the future of museums.

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[36] Erkki Huhtamo, "Museums, Interactivity, and the Tasks of 'Exhibition Anthropology,'" in *The International Handbooks of Museum Studies* (John Wiley & Sons, 2015), 259–77, https://doi.org/10.1002/9781118829059.wbihms312.

[37] Nancy Proctor, "Mobile in Museums: From Interpretation to Conversation," in *The International Handbooks of Museum Studies* (John Wiley & Sons, 2015), 499–525, https://doi.org/10.1002/9781118829059.wbihms322.

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6. Appendices

6.1 Photographs of the Selected Objects

Figure 1 1952.04.0128. Figurine of a woman. Photo: Frida Berntson.

Figure 2 1971.05.0003. Wooden table. Photo: Frida Berntson.

Figure 3 1923.06.0545. Sculpture of a dog. Photo: Frida Berntson.

Figure 4 Californian woven basket. Photo: Frida Berntson.

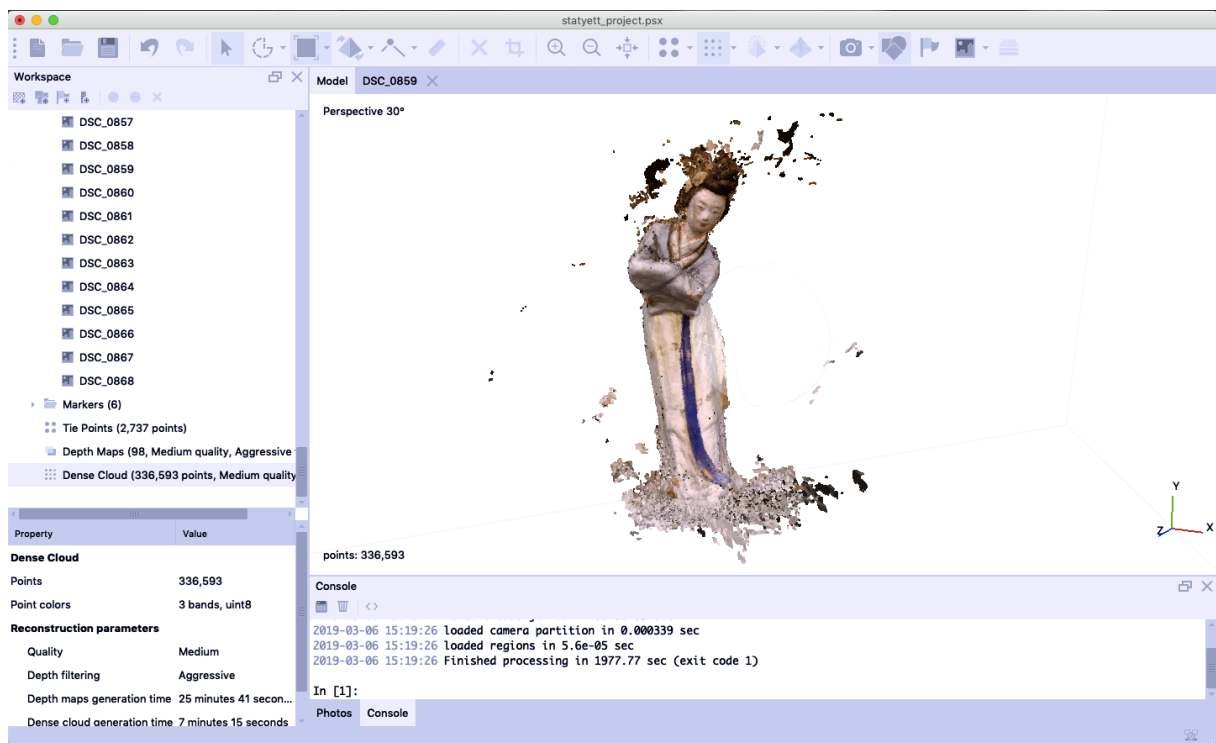## 6.2 Screen Shots From Making the 3D Models and the Application

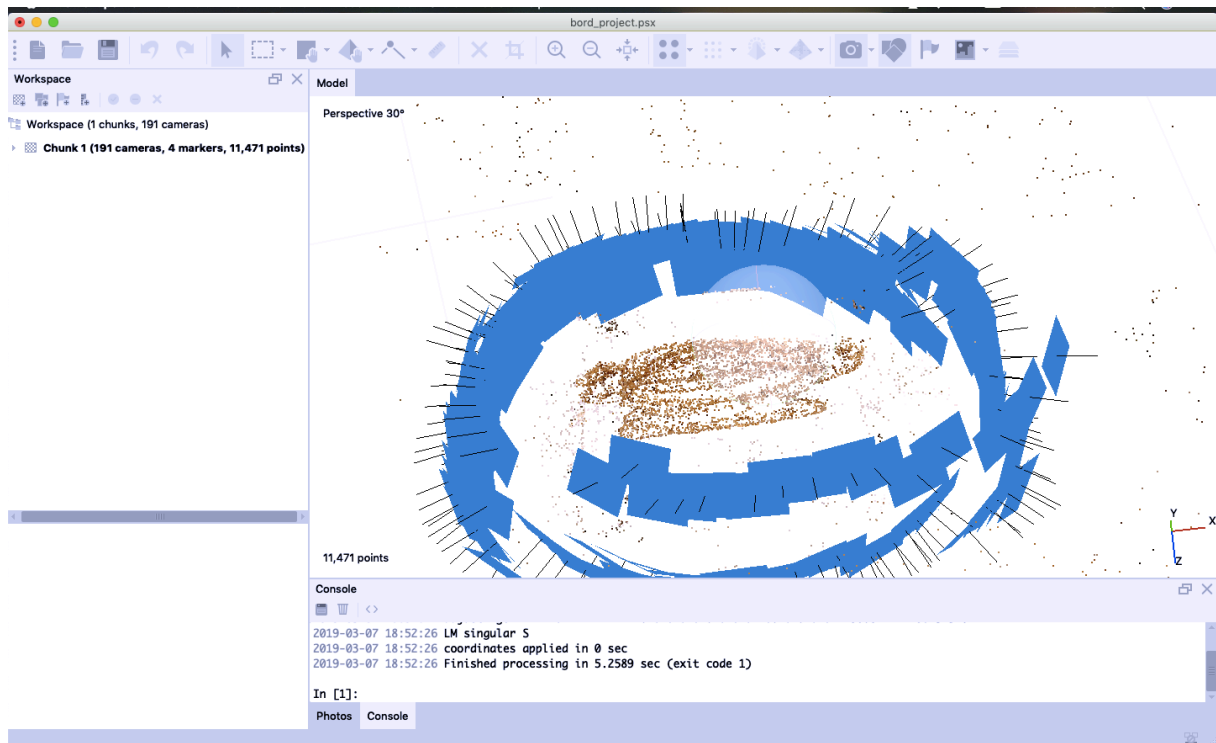*Figure 5 Working on the dense cloud of the figurine in Metashape.*

Figure 6 Photographs locations are visible, in the process of aligning photos of the table in Metashape.
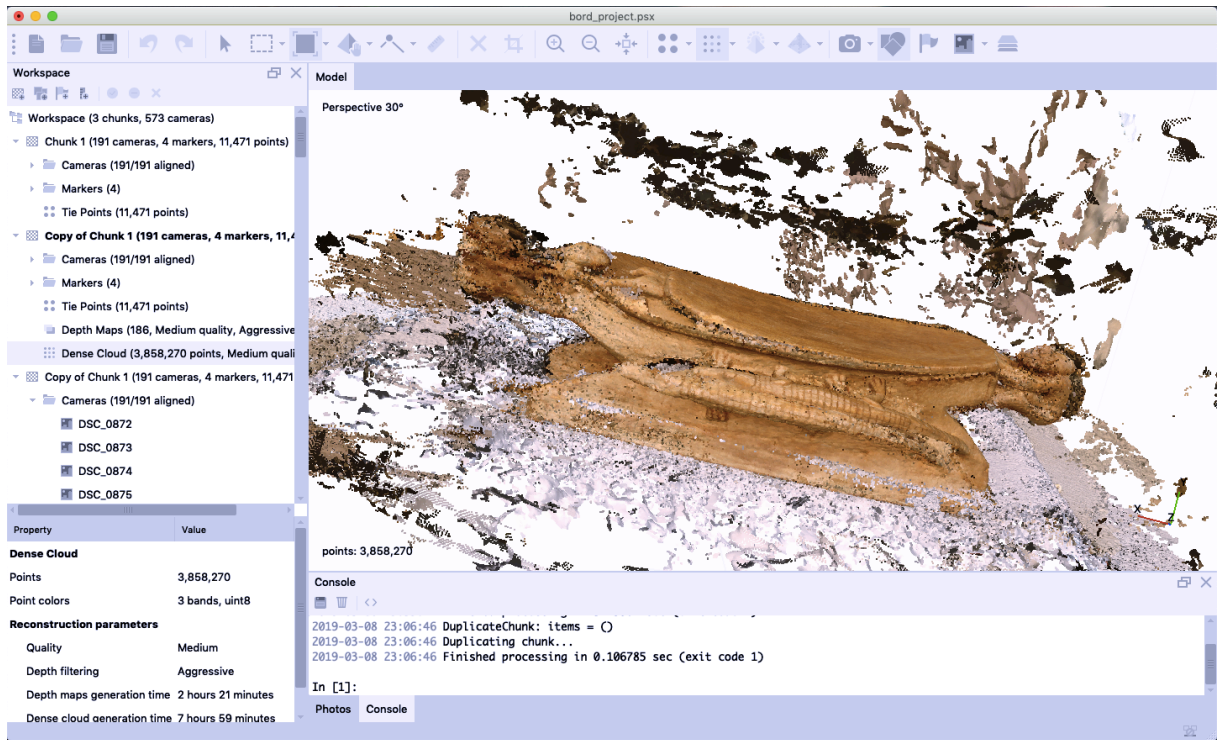
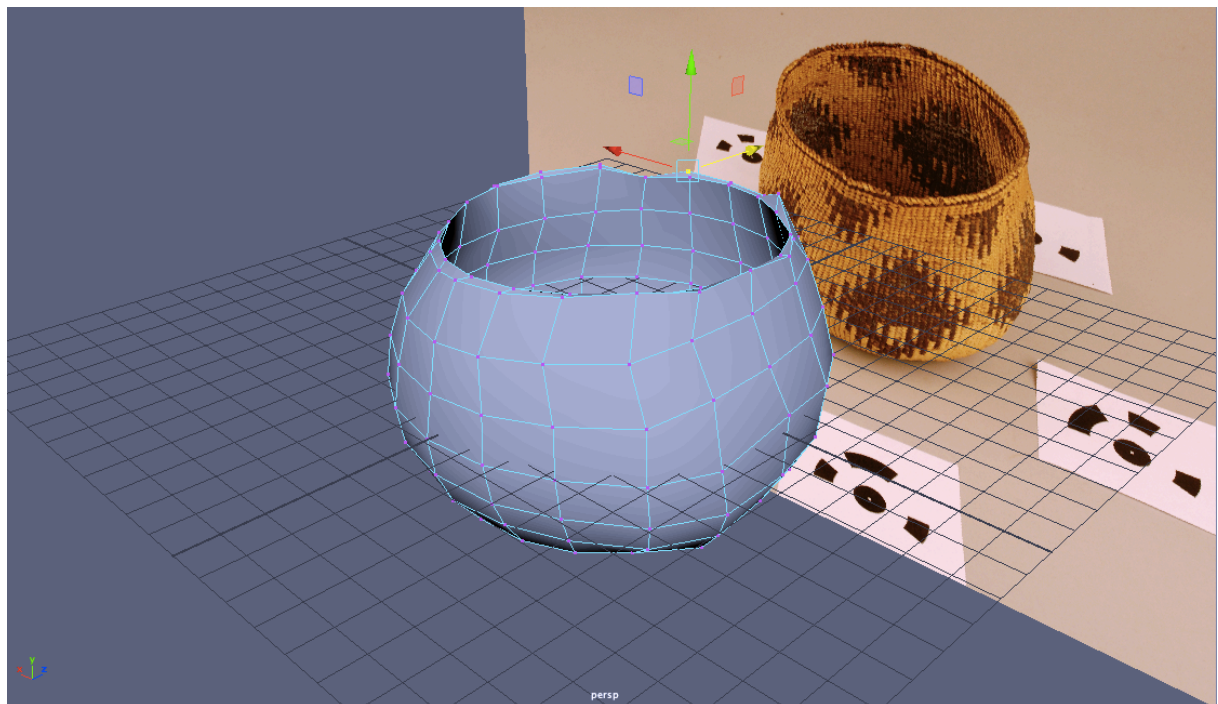*Figure 7 Editing the dense cloud of the table in Metashape.*

Figure 8 Making a representation of the basket in Autodesk Maya using a photo for tracing.
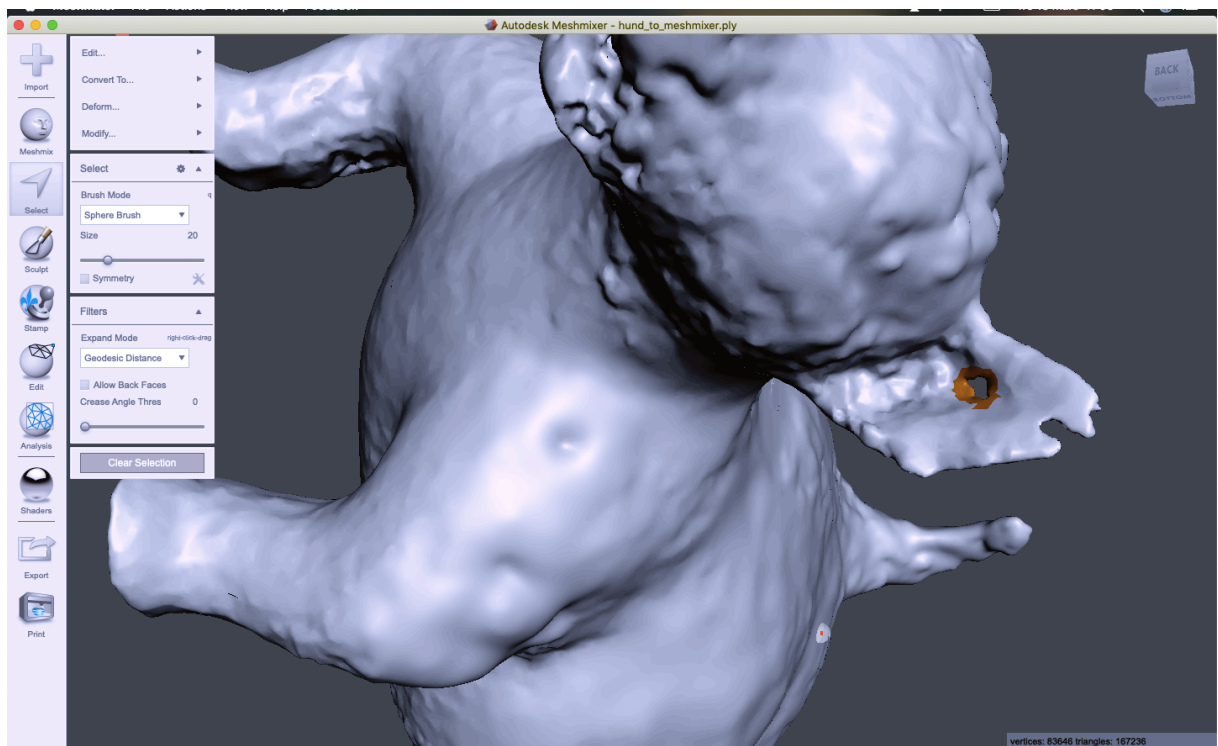
Figure 9 Dense cloud of the dog before editing.

Figure 10 Editing the 3D model in Meshmixer.

6.3 Pictures Used as AR Targets

Figure 11 Icon made by Freepik from www.flaticon.com.

Figure 12 Icon made by Freepik from www.flaticon.com.

Figure 13 Icon made by Freepik from www.flaticon.com.

Figure 14 Icon made by Smashicons from www.flaticon.com

6.3 Pictures of the Exhibition and the Application Being Used

Figure 15 One of the information screens. Photo: Frida Berntson, 2017.

Figure 16 The water area in the exihibition. Photo: Frida Berntson, 2017

Figure 17 Application start page.

Figure 18 Screen shot of the basket in AR camera mode. Photo: Frida Berntson, 2019.

Figure 19 The application being used. Photo: Frida Berntson, 2019.

Figure 20 The object view. Photo: Frida Berntson, 2019.

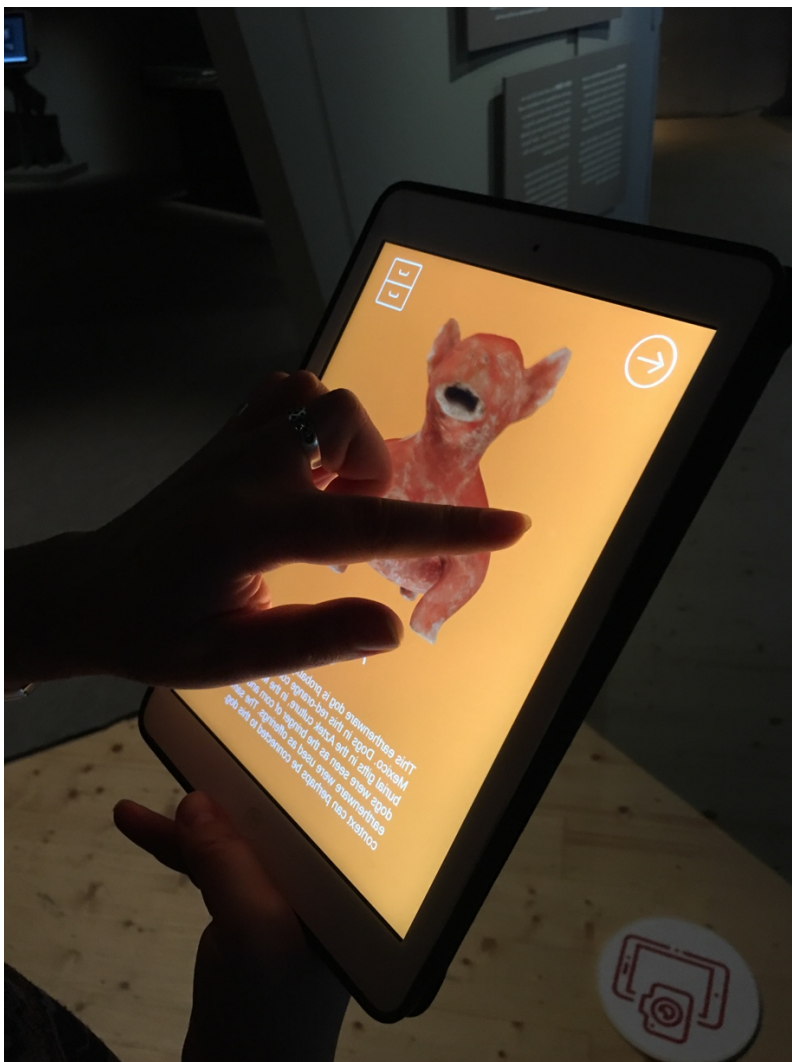*Figure 21 Screen shot from the application. Photo: Frida Berntson, 2019.*

Figure 22 Exploring the object mode. Target in the background. Photo: Frida Berntson, 2019.

This earthenware dog is probably from Colima in Mexico. Dogs in this red-orange color was common burial gifts in the Aztek culture, in the Mayan culture dogs were seen as the bringer of corn and dogs in earthenware were used as offerings. The same context can perhaps be connected to this dog.

Figure 23 Object view.