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# Interactive Museum Exhibit Featuring Pueblo Influence on New Mexican Contemporary Architecture

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# Interactive Museum Exhibit Featuring Pueblo Influence on New Mexican Contemporary Architecture

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An Interactive Qualifying Project Submitted to the Faculty of WORCESTER POLYTECHNIC INSTITUTE completed at the Santa Fe Project Center in partial fulfillment of the requirements for the Degree of Bachelor of Science



**WPI**

**Submitted By:**  
Colin Ancalmo  
Hannah Báez  
Noah Budris  
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**Submitted On:**

October 10, 2018

**Submitted To:**

Professor Lauren Mathews, Worcester Polytechnic Institute

**Sponsoring Agency:**

Dr. Theodore Jojola, University of New Mexico Indigenous Design and Planning Institute

This report represents the work of four WPI undergraduate students submitted to the faculty as evidence of completion of a degree requirement. WPI routinely publishes these reports on its website without editorial or peer review. For more information about the projects program at WPI, please see: <http://www.wpi.edu/Academics/Projects>.

## **Abstract**

Indigenous communities often face cultural misrepresentation in educational environments such as museums. This report examines the manifestation of this problem within Puebloan architecture in New Mexico. The University of New Mexico's Indigenous Design and Planning Institute seeks to address this issue by designing an interactive museum exhibit that emphasizes the evolution and meaning of Puebloan architecture. This report outlines our contribution to this initiative by providing extensive historical background on the relevant Pueblo tribes, their representation in museums, and the technology necessary to create an interactive exhibit. We constructed a partial exhibit prototype showcasing the physical, cultural, and influential aspects of the Old Zuni Mission. The prototype of this building is part of a larger exhibit initiative started by iD+Pi, iArchitecture. Additionally, we provided various representations of platforms to present this information in a meaningful and culturally accurate way.



## **Acknowledgements**

This research was supported by Worcester Polytechnic Institute and the University of New Mexico's Indigenous Design and Planning Institute. We would like to thank our sponsors Dr. Theodore Jojola, Ms. Michaela Shirley, and Ms. Chelsy Begay from iD+Pi for their support and for all of the incredible educational opportunities they have provided us. We would also like to thank Professor Lauren Mathews, Professor Melissa Butler, and Professor Fabio Carrera from Worcester Polytechnic Institute for their guidance in the development of our report and for their support during the IQP process.

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We would like to thank Tourism Director Tom Kennedy and Tourism Board Member Wells Mahkee from the Zuni Pueblo for the informational tour of the Old Zuni Mission. We would also like to thank them for their extensive historical insight and for providing our team with a new understanding of how this project could aid the community.

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We would like to thank IDEUM for the informational tour they provided to our team and sponsors. We would also like to thank them for introducing us to the different types and abilities of touch tables.

We would finally like to thank UNM's Christopher Stewart and Sergio De la Cruz for their help during our 3D printing process.

## Executive Summary

The Puebloan Tribes of New Mexico embody the diversity of their culture, most notably expressed through their unique and evolving architecture. Traditionally, Puebloan architecture represents their cultural beliefs and traditional values by embedding them within the physical design and location of their buildings (Grugel, 2012; Preiser et al., 2015). Through external influence over time, their buildings of adobe walls, viga and latilla roofs, and canale water drains greatly informed the contemporary architectural landscape of New Mexico (Preiser et al., 2015).



*Figure 1 - Traditional Zuni Pueblo Community Design (Curtis, E.S., 1903, A Corner of Zuni)*

The general public, however, lacks public understanding of the indigenous architects that developed this style and the cultural practices that influenced its design (DataUSA, 2015). This lack of understanding has been primarily due to ineffective public education within museums (Parezo, 2015). Museums have historically aimed to accurately portray indigenous peoples. However, the past methods of exhibition design often result in a fundamental misrepresentation of native cultures (King, 2016). This issue has manifested itself within the Puebloan tribes through a prevailing societal disacknowledgement of their influence on contemporary architecture (Windmuller-Luna, 2017; Parezo, 2015).

Our sponsor, the University of New Mexico's Indigenous Design and Planning Institute (iD+Pi), seeks to educate the public on indigenous architectural design through academic, tribal, and professional processes. iD+Pi is currently working to create a museum exhibit that showcases contemporary Puebloan architecture through an interactive representation of six Puebloan buildings, a project named iArchitecture (University of New Mexico, 2016). iD+Pi began this initiative with documentation of important physical features of Puebloan architecture, interviews with tribal members from each site, and two potential exhibit designs. Our task was to further this project by providing a partial exhibit prototype representing one of the six sites, the Old Zuni Mission. Additionally, we provided iD+Pi with a methodology for applying our findings to the remaining sites, as well as a framework for the various interactive components of this exhibit.

To complete this, we first identified the physical, cultural, and influential learning outcomes depicted through the iArchitecture exhibit. These learning outcomes focus on how we want to alter the visitors' perception of Puebloan architecture and the new knowledge they should obtain about the respective cultural importance of each building. We defined the learning outcomes in a general manner and later explained how they were represented within the Old Zuni Mission. To establish the physical learning outcome, we utilized last year's IQP report in conjunction with readings provided by and meetings with our sponsor (DeOliveira et al., 2017). These documents allowed us to initially list important architectural features, then convert them into a general learning goal. To create the cultural and influential learning outcomes, we met with representatives from Santa Fe's Atkin Olshin Schade (AOS) Architects who have extensive experience renovating Puebloan buildings while maintaining cultural accuracy. We discussed questions they find most important to ask when incorporating cultural influences in contemporary design and architecture. From this objective we determined the important physical features were adobe, canales, ramadas, vigas, niches, and splash boards. The learning outcome determined from this list was: *Visitors will be able to identify specific architectural components commonly represented within Puebloan architecture.* Additionally, we hoped to depict how these features are common among different Puebloan tribes and have unique creation methods or tribal meanings. This spawned the second physical learning outcome: *Visitors will be able to identify the composition, uniqueness, and architectural purpose for each specific site's physical features.* Our meeting with AOS Architects gave us insight on the importance of realizing the cultural importance of the space around each building and how tribal values commonly intersect with architecture. The cultural learning outcome developed from this was: *Visitors will be able to recognize that Puebloan architecture often embodies community, spirituality, and reactive beliefs and values.* This meeting also informed us on how Puebloan architecture can have aspects that change with time, but has certain features that stay permanent through renovations. This created our influential learning outcome: *Visitors will be able to recognize that contemporary Puebloan architecture has a base in traditional design but has changed as modernized worldviews become more prevalent.*

Next, we developed 3D digital exhibit models for the selected contemporary Puebloan buildings using Light Detection and Ranging (LiDAR) scanning technology. Our sponsor provided us with a raw ground LIDAR point-cloud dataset of the Old Zuni Mission. To utilize

this technology, we processed and cleaned the raw LIDAR point-cloud dataset using FARO Scene, Autodesk ReCap 360, GeoMagic Design X, and Autodesk 3DS Max software to allow for digital interactions.



Figure 2 - Photo of Old Zuni Mission S-E View

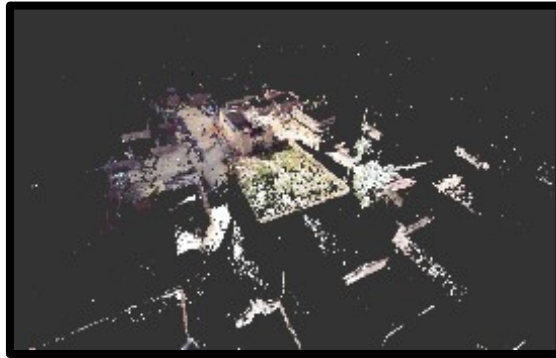


Figure 3 - Original Point-Cloud Data



Figure 4 - LiDAR image of Old Zuni Mission S-E View

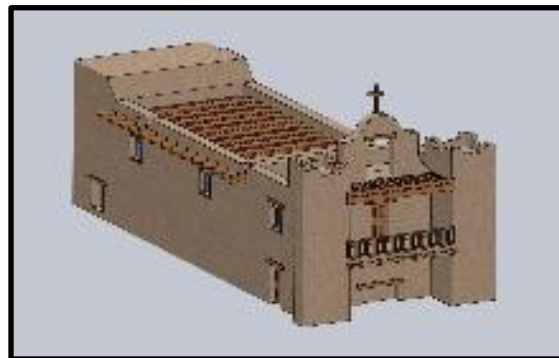


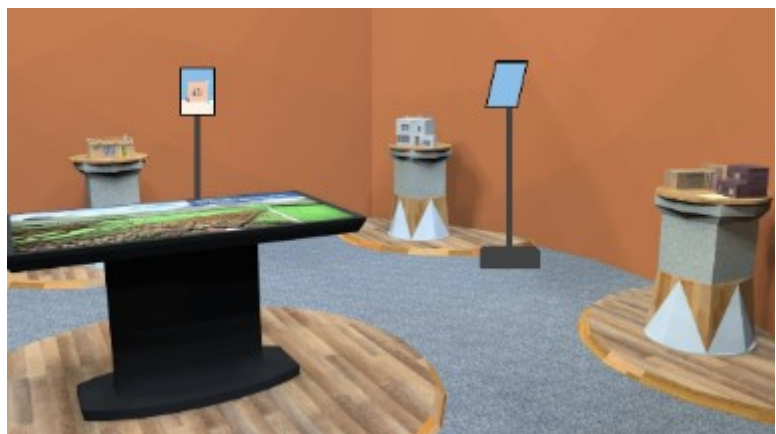
Figure 5 - SolidWorks Model of Old Zuni Mission

We recorded exact geometric dimensions to recreate the building's structure in SolidWorks for 3D printing applications. In addition, we created and rendered high quality point-cloud fly-through videos highlighting architectural details. To confirm our model accuracy, we used exact LiDAR geometric measurements and on-site photographic comparisons to compare the geometric results to their respective physical counterparts. Through this process, we concluded there was little dimensional and scalar variation between our digital model and the actual site.

After the 3D digital models were completed, we then constructed a working, physical prototype of the interactive museum exhibit. The prototype exhibit was created in three parts, a 3D printed model, an iPad, and a touch table. These methods of interactivity were chosen due to the accessibility to 3D printers and the availability of a touch table at UNM. The learning outcomes were then divided among the three different media. The 3D printed model represents the physical architectural learning outcome of the site, the iPad describes the specific

contemporary influences and community/spirituality aspects of the corresponding site, and the touch table provides further information on the materials used and creation of the physical elements depicted by the 3D printed model. First, we created the 3D printed model. To do this the digital model previously created in SolidWorks was 3D printed and assembled. Along with the scaled down model of the Mission, another smaller model was printed in order to act as a tangible for the touch table. The larger model was painted with acrylics and sand was added in order to resemble the texture and color of the Mission. There were four main physical architectural elements associated with the Zuni Mission; adobe, latillas, vigas, and canales. In order to transform the 3D printed model into an interactive learning tool, buttons were installed in the model. When any of these buttons is pressed, a LED (Light Emitting Diode) lights up next to the corresponding physical architectural element's name. The touch table was then used in order to display the specifics regarding the physical elements depicted by the 3D printed model.

In addition, an app was developed for the touch table that would facilitate this interactive portion of the exhibit. When the 3D printed tangible for a site is placed on the touch table screen and the user selects the site, the user is taken to a page where they can learn more about the materials used and the creation procedure used for each architectural elements for that site. There is also an opportunity included for the user to explore a flythrough of the inside and outside of the site. The iPad further provides information on the contemporary influence and community/spirituality for each site. Another app was then developed for the iPad in order to communicate this information and in order to add interactivity. A brief history video of the site was included in order to provide the user with the introductory foundation recommended for fully understanding the material. A video describing the community and spirituality aspects of the site's design was added that includes flythroughs throughout the building in order to provide context to the user. A final interactive aspect was included to showcase site's contemporary influence. For this, we developed an interactive timeline depicting the site's



*Figure 6 –IPCC Exhibit Design*



change over time. For the entire exhibit we focused on ensuring that we were able to reach visitors with two levels of education. One reaches visitors with no foundational knowledge of contemporary Puebloan architecture, and the second reaches visitors who would like to expand their knowledge. Our exhibit also provides a shared experience between the visitors for all methods of interactivity.

Lastly, we designed a guided survey to receive feedback on the prototype and a technical guide providing specific instructions on how it was created. The group that was used to test our prototype was made up of WPI college students who had relatively little knowledge of Puebloan architecture or culture. This made them ideal subjects to determine how well the exhibit conveyed our learning objectives because they would have no knowledge before viewing the prototype that would influence their answers on the survey. Each question asked in the survey was meant to help answer whether the information learned by the subjects matches with our learning objectives. From the survey results, the average percentage of understanding of each learning outcome was calculated. These results are outlined in Figure 7, the graph below.

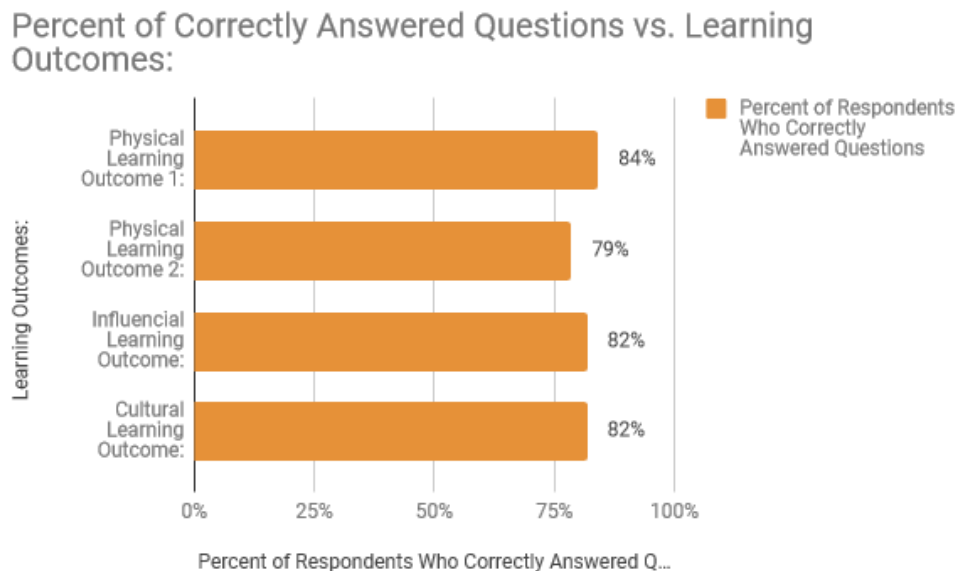


Figure 7 - Percent of Correctly Answered Questions Vs. Learning Outcomes Chart

In addition to being a comprehensive instruction manual on how to replicate technical aspects of the prototype, our guide includes a template for each site, organizing learning goals by which interactive medium will convey them. While the guided survey allowed us to assess the effectiveness of the Zuni Mission prototype, the instruction manual allows iD+Pi to repeat our processes for the remaining Pueblo sites and build off of our work to complete a final exhibit.

We delivered to iD+Pi a partial exhibit prototype including a 3D printed model, a touch table storyboard, and an iPad storyboard. Additionally, we included two apps condensing this information into a more user-friendly application. Each of these focused on the Old Zuni Mission but included a general framework for the remaining sites. Part of the touch table storyboard included flythroughs examining the various parts of the Old Zuni Mission. We recommended to iD+Pi that they convert all LiDAR flythroughs into real-time, interactive touch displays of the corresponding components.

Next, we provided iD+Pi with recommendations determined from our guided survey on prototype exhibit use. Once the exhibition is further finalized with content and models of all the six Puebloan architectural sites, we recommended that iD+Pi conduct two focus groups. The first focus group will be with liaisons from the represented Pueblos to evaluate the existing cultural accuracy and offer insight on how to further the cultural benefits of the project. The second focus group will be with museum visitors at the Indian Pueblo Cultural Center (IPCC), the future location of the iArchitecture exhibit. This will offer information regarding how intuitive, engaging, and informational the exhibit is.

## Authorship:

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1.2 Tribes, Society, and Culture in New Mexico	Alex Spielman	Hannah Baez, Colin Ancalmo
1.3 Architecture of the Puebloan Tribes	Hannah Baez	Noah Budris Alex Spielman
1.4 Museum Exhibitions	Colin Ancalmo	Noah Budris Hannah Baez
1.5 LiDAR	Noah Budris	Colin Ancalmo Alex Spielman
1.6 Past and Completed Work	Noah Budris	Colin Ancalmo Alex Spielman
2.0 Methodology	Noah Budris, Colin Ancalmo, Hannah Baez, Alex Spielman	Noah Budris, Colin Ancalmo, Hannah Baez, Alex Spielman
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2.3 Constructed a Working, Physical Prototype of the Interactive Museum Exhibit	Hannah Baez	Alex Spielman Noah Budris
2.4 Assessed Exhibit Effectiveness Relative to Learning Outcomes and Provided Exhibit Framework for Further Development	Alex Spielman Colin Ancalmo Noah Budris	Hannah Baez Colin Ancalmo
3.0 Results	Noah Budris, Colin Ancalmo, Hannah Baez, Alex Spielman	Noah Budris, Colin Ancalmo, Hannah Baez, Alex Spielman
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3.4 Assessed Exhibit Effectiveness Relative to Learning Outcomes and Provided Exhibit Framework for Further Development	Alex Spielman	Colin Ancalmo, Hannah Baez
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4.3 Focus Group Evaluation Guide	Alex Spielman Noah Budris	Noah Budris, Colin Ancalmo, Hannah Baez, Alex Spielman
5.0 Conclusion	Noah Budris Colin Ancalmo	Noah Budris, Colin Ancalmo, Hannah Baez, Alex Spielman
Appendices	Noah Budris, Colin Ancalmo, Hannah Baez, Alex Spielman	Noah Budris, Colin Ancalmo, Hannah Baez, Alex Spielman

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## **1.0 Introduction and Background.**

Museums have historically aimed to accurately portray indigenous peoples. However, the past methods of exhibition design often result in a fundamental misrepresentation of native cultures (Steger et al., 2014). As a result, a misleading image of indigenous cultures is facilitated within the museum setting through their artifacts, art, and architecture (Cordell, 1979; King, 2016).

Museums are a primary and accessible mode of education for the public on American history and culture. Nevertheless, modern exhibits lack the diversity of indigenous lifestyles and fail to address the true nature of cultural practices (Parezo, 2015; Windmuller-Luna, 2017). One of the most populous groups to face misrepresentation on the global scale are the various Native American nations. The public portrayal of native communities has had minimal focus on their contributions to contemporary society (Windmuller-Luna, 2017). This issue has manifested itself within the Puebloan tribes of New Mexico through the incomplete attribution of their vernacular architecture--the locally and culturally influenced architecture of their people. Frequently, non-indigenous societies have views of Puebloan architecture that are limited by generalized presentations of historical indigenous structures such as teepees or igloos. This image diminishes the recognition of Puebloan tribes' contributions to the field of architecture (University of New Mexico, 2016). As a result, the spirituality embedded in Puebloan architectural planning and community layouts remains unrecognized by non-native society (Jojola, 1990).

Contemporary Puebloan architecture lacks public recognition of the indigenous architects that developed the style and the cultural practices that influenced its design. As a result, young Puebloan architects are losing their connection with the cultural importance of the traditional architecture (University of New Mexico, 2016). Since the twentieth century, inaccurate museum exhibits have unknowingly facilitated a misrepresentation of Pueblo architecture and an underrepresentation of Pueblo architects (University of New Mexico, 2016). Currently, 0.025% of architects in US have native roots, while Native Americans make up 2% of the population (DataUSA, 2015). Modern architectural exhibit designers, in response to this issue, have instituted a more inclusive design process with indigenous architectural representatives. The resulting exhibits allow Native American nations such as the Puebloan tribes to oversee the representation of their respective cultures (King, 2011). Likewise, this issue motivated the involvement of the University of New Mexico (UNM)'s Indigenous Design and Planning

Institute (iD+Pi). iD +Pi aims to educate faculty, students, professionals, and policy leaders in culturally appropriate design and planning practices (University of New Mexico, 2016). This organization hopes to create an interactive exhibit addressing the major architectural designs and contributions of the Pueblo tribes forgotten by contemporary society (iD+Pi, 2016). An Interactive Qualifying Project (IQP) team from Worcester Polytechnic Institute (WPI) assisted with the early stages of this initiative, proposing 3D designs representing Puebloan architecture for this exhibit (DeOliveira et al., 2017). Our project focuses on applying these designs to prototype development for this exhibit.

A thorough cultural understanding of the Puebloan tribes, their histories, and their architecture is necessary for our goal of assisting iD+Pi's mission. This chapter serves to provide necessary background on the importance and historical value of Puebloan architecture, successful museum exhibit design and modeling, relevant necessary equipment, and the current state of the iArchitecture initiative.

## 1.1 History of the Puebloan Tribes.

The Puebloan tribes of New Mexico were traditionally agrarian societies and their architecture, as well as their relationships with other groups, have caused them to diversify. During the 1300s the Puebloan tribes split into different groups which still exist today. Each Puebloan tribe is an independent and separate community, sharing fundamental similarities among their languages, architecture and cultures (Swentzell, 1999). These tribes include the Isleta, Acoma, Ohkay Owingeh, Zuni, Pojoaque, and Santa Clara, in addition to fourteen others in New Mexico. A map of twenty-first century Puebloan communities can be seen in Figure 1 below.

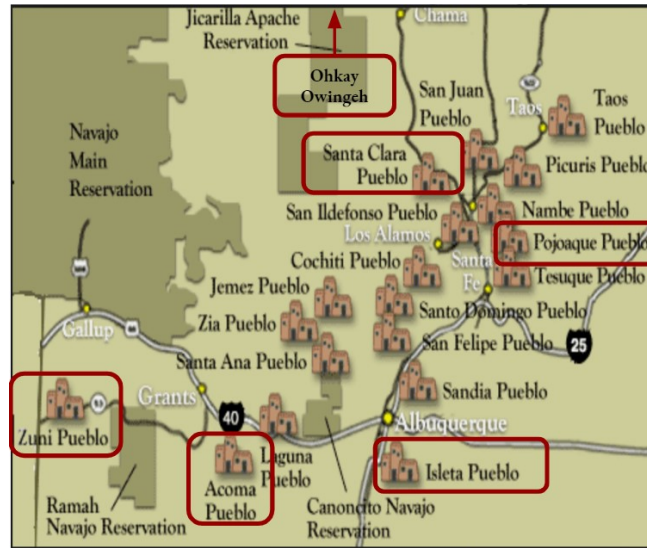


Figure 1 - Map of current Puebloan communities in New Mexico (Gentili, 2015)

The arrival of the Spanish in the 1500s marked a dramatic shift in the lives of the Puebloan people (Preucel & Liebmann, 2007). The conquistadors forced their culture and religion onto the indigenous peoples (Birchfield, 2009). In 1680 the Pueblo revolt occurred over a period of 12 years, where the tribes were able to put aside their differences and unify to push back the foreign invaders. As a result, there was a sharing and merging of architectural styles and cultures between Puebloan tribes (Preucel & Leibmann, 2007). Despite being re-conquered by the Spanish, much of the traditional Puebloan culture remained, simply integrating what ideas the Spanish forced on them (Preucel & Liebmann, 2007). Then, in the 1800s the land of the Puebloans was seized by the American government. While being given the ability to govern themselves, there were still numerous attempts to convert them to American culture (Grugel, 2012).

The prolonged occupation first by the Spanish and later by the Americans have caused numerous changes to Puebloan architecture and culture. When the Spanish occupied what is now New Mexico, their attempts to force the Puebloan tribes to assimilate into their culture caused architectural styles to merge with each other, along with the adoption of Spanish building techniques. There were similar practices of assimilation during times where America held influence in the New Mexico area, forcing ‘American’ culture on the younger Puebloan generation. While the government formed laws to protect Puebloan rights on reservations, their communities were often overlooked economically, with some falling into poverty (Grugel, 2012). From an architectural standpoint, this has all led to a decrease in the regional community

care for Puebloan architectural traditions as well as a decrease in the information shared pertaining to Puebloan architectural practices (Birchfield, 2009).

## 1.2 Tribes, Society, and Culture in New Mexico.

Despite having a number of differences, the nineteen Puebloan tribes in New Mexico also have similarities among their societies and cultures. Both the social and religious organizations of Puebloan communities emphasize the close relationship between individuals and their respective Puebloan tribe (Grugel, 2012). This encourages many people living in the tribes to remain there for schooling and eventually live long-term at the Pueblo itself. As a result, everyday life is permeated with Puebloan societal beliefs and values. A common Puebloan societal value is that an individual subordinates his or her interests to those of the community as a whole. Personal ambition, therefore, is not valued like it is in American culture, and is generally not considered a socially approved characteristic. Instead, outstanding performance for the benefit of the group is considered to be paramount (Grugel, 2012). Consequently, Puebloan communities succeed or fail as a whole, with much of the wealth being distributed evenly among its people and public places.

Religious beliefs also heavily intertwine with many aspects of Puebloan life and culture. For example, much of Hopi Pueblo spirituality is tied to agriculture with many of their traditional ceremonies and rituals center around it (Birchfield, 2009). The use of religious ceremonies is not uncommon in Puebloan communities and is a part of everyday life for some (Grugel, 2012). In addition to their traditional religious beliefs, they also hold versions of the Christian belief system as a result of previous assimilation, modified to be compatible with their own traditional views (Birchfield, 2009).

## 1.3 Architecture of the Puebloan Tribes.

In this section, we describe the vernacular architecture of the Puebloan tribes and the impact by contemporary society on their architecture. First, we discuss pre-twentieth century Puebloan architecture, the compositional elements of traditional Puebloan homes, and their purpose. Next, we describe the current state of contemporary Puebloan architecture by exploring how it is affected by contemporary architectural views. Although each of the nineteen Puebloan tribes is unique unto themselves, the architecture discussed in this section will be representative of the similarities between the styles of each tribe, and will not discuss the specific differences



between them. This is due a lack of available information on their specific tribal architectures due to the confidential nature of the Puebloan tribes and spiritual belief system. This belief system, as previously stated, emphasizes an effort to keep their culture personal and protected.

### **1.3.1 Vernacular Architecture of the Puebloan Tribes.**

Vernacular architecture is defined as an architectural style that reflects a culture's traditions, the needs of their community, and the construction materials on hand (Preiser et al., 2015). This chapter uses the term vernacular architecture with reference to traditional pre-twentieth century Puebloan architecture.

The Puebloan people, although made up of different and unique tribes, share a similar culture due to their shared history. One of the most pronounced similarities between them is the shared cultural emphasis on religion and spirituality, which is visible in their architectural styles and community planning (Preiser et al., 2015). Puebloan spirituality is based on a belief that all animate and inanimate creatures and objects share a common "breath" that is essentially life. All things are seen as alive, and a part of the "Earth-Mother" (Preiser et al., 2015). The Puebloans spiritual model of the world necessitated the development of a community layout that was focused on togetherness.

A community aspect to the design and layout of the Puebloan homes was paramount. Puebloan homes were typically amassed together and comprise multiple floors. The bottom floor was normally a storage room, and the floors above it could be reached by use of a ladder. As members of the family were married and began their own families, more rooms would be added to the overall structure. These rooms were typically added in a step-format (USDA, 1975). This "step-format" can be seen in Figures 2 and 3. These large community buildings often also include ceremonial rooms called kivas. These rooms were spherical in nature and were the spiritual center of the community. More than one would be added in order to adhere to the large population (USDA, 1975).

Traditional Puebloan homes were built with adobe bricks composed of mainly mud, clay, and brush. These bricks dried in the sun and were given the name "sun-bricks". These buildings were often referred to as adobes due to their main construction material. Adobe was the chosen construction material of the Puebloans due to the dry desert landscape on which they lived. This is also due to the few trees available in the desert landscape needed to construct a community entirely out of wood. Although the fertility of the desert varied depending on the location of the

tribe, a consistent plethora of dirt and brush could be found and used as a building material, regardless of the tribe's location (USDA, 1975). Once built, a Pueblo adobe home would allow and keep cool air in during the summer and would keep its residents warm during the winter. In order to support the roof of the building, long wooden beams called vigas were set across the roof and used the walls as support. These vigas were commonly made from the wood of large pine trees. The density of these trees varied depending on the location, but were common enough to provide the structural support necessary in a Pueblo home. Flat wooden slabs or sticks called latillas were placed in either a perpendicular or clockwise fashion on top of the vigas in order to create support for the adobe roof. Outside of the adobe buildings ramadas were constructed to shield the Puebloans from the sun while they worked and cooked outside. A ramada is a four-pole structure with a roof of branches and brush (USDA, 1975). An example of vigas and latillas can be seen in Figure 4 and an example of a ramada can be seen in Figure 5.



*Figure 2 - Traditional Zuni Pueblo Community Design (Curtis, E.S., 1903, A Corner of Zuni)*



*Figure 3 - Traditional Taos Pueblo Community Design (Galuzzi, L., Taos Pueblo)*



*Figure 4 - Vigas and Latillas (Adams, 2018)*



*Figure 5 - Taos Puebloan Ramada (Klein, n.d.)*

### 1.3.2 Impact by Contemporary Society on Classic Puebloan Architecture

The architectural style in the contemporary Southwest represents an adaptation of elements appropriated from earlier Hispanic and Native American architectures (Preiser et al., 2015). These forms were previously rejected and neglected by Anglo immigrants during the second half of the nineteenth century, but experienced a revival, known as the “Pueblo Revival”, in the first half of the twentieth century (Preiser et al., 2015). Since the Pueblo Revival, this style of architecture has become the staple architecture within the southwestern region of the United States. An example of contemporary Pueblo architecture can be seen in Figure 6 and the inside of a contemporary Pueblo style home with contemporary vigas and latillas be seen in Figure 7.



*Figure 6 - Exterior Example of Contemporary Puebloan Architecture with Visible Faux Adobe and Vigas (Beuerlein, 2015)*



*Figure 7 - Interior Example of Contemporary Puebloan Architecture with Visible Vigas and Latillas (Gittings, 2012)*

The homes depicted contain modernized elements of the Puebloan architectural style such as the cubic design, rounded edges, faux-adobe, vigas, and latillas. These homes are now built with modern day construction materials and the lack of community planning in these contemporary homes serve individualistic purposes rather than the close community-driven and spiritual purposes. The elements that served a structural purpose in older buildings have been co-opted for aesthetic purposes (Parsons, 1939). This change is due to the values and lifestyle of the main demographic in the region. In contemporary New Mexico, indigenous communities only make up 8.6% of the total population and indigenous architects make up a small unrecorded percentage of New Mexican architects (DataUSA, 2015). This has resulted in a shift from spiritually-driven architecture towards architecture that fulfills more individualistic means. Due to this change in demographics and values, non-indigenous society overlooks the meaning

behind elements of Pueblo architecture and their Puebloan creators are not given credit for their founding design (Preiser, et al., 2015). This impact by contemporary society on classic Puebloan architecture is seen by the University of New Mexico's (UNM) Indigenous Design and Planning Institute (iD+Pi) as a call to action. iD+Pi has instituted a goal of educating architects, educators, and the general public on culturally appropriate architectural designing and planning. They envision a future exhibit aiding their goal at the Indian Pueblo Cultural Center (IPCC). The incorporation of indigenous history in museum exhibits and their development are discussed in the section below.

## 1.4 Museum Exhibitions

In this section, we identify and consider the issue of culturally appropriate indigenous representation in the context of past and current historical museum exhibits. Next, we analyze how museums nationwide have incorporated Native perspectives. We then review the forms in which exhibitions generally present information and how multimedia technology can increase understanding on anthropological topics of architecture and culture.

### 1.4.1 Cultural Representation in Museums.

Anthropological professionals view museums of the nineteenth and twentieth centuries as the foundation of public American anthropology (Parezo, 2015). Indigenous cultures and some curators have, however, criticized museum exhibition designers for their inaccurate coverage of indigeneity. The Puebloan tribes have “the right to maintain, protect, and develop the past, present, and future manifestations of their cultures...” pertaining to their “archaeological and historical sites” under the *United Nations Declaration of the Rights of Indigenous Peoples* (United Nations, 2008). Exhibit designers were often constrained by time, budget, and available resources--both physically by materials and conceptually with often limited access to indigenous societies as outsiders. As a result, designers unintentionally overlooked these rights, portraying instead a generalized and fictitious image of indigenous communities (King, 2016).

Anthropologist Nancy Parezo defines the ways in which most misrepresentations occur through the two main models of exhibition: non-collaborative and collaborative. Non-collaborative modes do not include the indigenous peoples they are representing during the creation process, while collaborative modes promote and use indigenous input and review. Multiple contemporary indigenous communities have concerns regarding non-collaborative

practices as curators frequently trade historical accuracy for aesthetic looks and omitted information (Parezo, 2015). The first notable case of non-collaboration was in the Columbian Exposition of 1893, where 13 major indigenous nations across America--one of which was titled “the Pueblos” of New Mexico--were truncated into three generalized adaptations due to time and space restrictions (Parezo, 2015). Had indigenous leaders been involved in the process, curators could have avoided the cultural mismatch that followed, a mixing of Zuni Tribe artifacts with Hopi lifestyles (Parezo, 2015). Linguistics professional Lisa King roots such incidents in a failure of the curation process and a violation of ‘rhetorical sovereignty’--indigenous people’s right to the specific rhetoric used to communicate their representations (King, 2011; King, 2016). Multiple anthropological specialists critique exhibits worldwide for lapses in rhetorical sovereignty, specifically pertaining to indigenous historical accuracy, diversity, and contemporary existence (Windmuller-Luna, 2017; Herzog & Stolte, 2012).

Leading into the twentieth century, curators progressed their design models in a culturally sensitive manner. Select museum exhibits in the process have laid the groundwork for collaborative approaches of exhibition with varying degrees of success. Respected curators agree that the leading causes of misrepresentation originate from non-collaborative exhibition methods (Herzog & Stolte, 2012; Windmuller-Luna, 2017). This is made particularly worse for the Puebloan tribes by the traditionally myopic archeological work that took place within the Albuquerque region (Cordell, 1979). Pioneers of the collaborative model believed that static snapshots of societies would fall prey to these issues since cultures are constantly evolving (Powell, 1887). Instead, representing contemporary culture is better done through exhibits that strive to “reflect new knowledge and ensure accuracy based on native knowledge” (Parezo, 2015).

Directly incorporating the communities that are portrayed in the exhibit itself has been the most successful approach for addressing cultural misrepresentations to date (Windmuller-Luna, 2017; King, 2011; Kee, 2014). Architectural-focused exhibits like *Contemporary African Architectures* in the Louisiana Museum of Modern Art (LMMA) included African community members in the design process to address historical contradictions and communicated their collaboration through exhibit labels. The National Museum of the American Indian (NMAI) implemented a similar system. The museum’s purpose design was “filtered through Native core cultural values and adapted accordingly” by addressing cultural sovereignty in a way “non-

Native audiences can comprehend and Native audiences can affirm” (King, 2011). NMAI curators were able to incorporate Native participation throughout the museum and exhibit process by identifying specific community curators to working alongside with. Critics claim the museum to be the first major public discussion identifying Native nations as contemporary with exhibits that “sets a unique precedent for history making and speaking sovereignty” (King, 2011; Herzog & Stolte, 2012).

It is critical to use the successes of the collaborative model as a guide to presenting contemporary nations that have been historically cast as static and generalized (Herzog & Stolte, 2012). This is true especially for architectural exhibits which commonly omit architectural diversity within village typologies, something that the Puebloan tribes have experienced for the last century (Windmuller-Luna, 2017; Parezo, 2015).

#### **1.4.2 Education Effectiveness of Multimedia Exhibits.**

Educators have frequently debated the mediums used to communicate complex topics to learners across disciplines (Kee, 2014). As museums play a large role in education outside the classroom space, it is important to understand how to effectively present information to an exhibit audience. Modern museums, often with science and technology focuses, further engage and educate their audience through the use of multimedia technologies (Kim, 2005). Multimedia is a content form that utilizes more than one medium to communicate information. In museum exhibit settings, this is often seen as interactive visual displays and physical kinesthetic components. Similar to how scientific exhibits balance scientific accuracy with entertaining visuals for the uninformed visitor, humanistic exhibits can also strive to balance cultural representation with engaging media (Kim, 2005).

One of the few criticisms of the aforementioned NMAI is that the exhibit lacked a clear mechanism by which audiences could engage with the subject matter. This ambiguity hindered designers’ plan to have visitors think critically on indigenous representation (King, 2011). Author and educator Kevin Kee identifies similar critical engagements as dependent on learner motivation, claiming one fundamental requirement for learner understanding is the interest and motivation of the teaching form itself (Kee, 2014). Universities around the globe have started to use interactive 3D virtual models specifically to expand historical education and anthropological analysis. Faculty at the University of Calgary showcased the technology’s abilities through an archeology exhibition on virtual Inuit dwellings models. By displaying three-dimensional

images, created by laser-based scanning, through a virtual environment, they created an interactive and inclusive space to engage with archaeology, increase community interest and raise accessibility to traditional architecture (Kee, 2014).

Critics, however, view isolated physical and digital 3D models within museum settings as decontextualized from their original focus. Architectural exhibits specifically “too often rely upon photographs, renderings, and models” that struggle to reflect a changing contemporary society (Windmuller-Luna, 2017; Kee, 2014). These monomedia forms can benefit from the use of additional communication tools for conveying cultural values. Scholars recognize that comparisons between individual monomedia are often problematic as different forms communicate different information. They agree instead that the combination of media with interactive elements result in more holistic cultural understandings (Kim, 2005; Beloff, 1994). By combining additional media tools with existing exhibit monomedia technologies, designers can work toward applying these benefits to architectural representations (Kee, 2014). Interactive multimedia are a new approach to teaching and analysis, powered by new 3D scanning and presentation technologies that can lead the way for future exhibition projects.

### 1.5: Technology for Building 3D Models.

Architects complete the architectural design process through the utilization of the above 3D technologies. The design process is the transition from a mental picture of a product to digital design, then to a working prototype. In order to accurately complete this process, LiDAR technology is used to initially measure an object, then additional programs are utilized to convert it into digital form (Bornman, 2015). In this section, we discuss the applications of this program.

#### **1.5.1: LiDAR.**

Light detection and ranging (LiDAR) refers to the usage of pulsating lasers to measure the depths of an object. It combines these measurements into a point cloud outlining the object's features (Hu, You, & Neumann, 2003). This theory of using lasers to measure objects has been used since the 1960's, and was initially used to measure the size of clouds (Bornman, 2015). Since then, LiDAR technology has vastly evolved, and is now applied to more situations. The most common applications of LiDAR include: urban planning, mapping earth topology, and understanding geographical changes over time (Inomata, Triadan, Flory, Burham, Ranchos, 2018).

Due to LiDAR's increasing potential, The National Aeronautics and Space Administration (NASA) is currently working with the U.S. Geological Survey (USGS) to create a nation-wide LiDAR dataset, mapping the topography of the United States. These governmental agencies have justified their initiative based on LiDAR's ability to provide accurate and necessary measurements regardless of its application (Stoker, Harding, & Parrish, 2008). Additionally, the USGS instituted a national LiDAR development effort, officially named the 3D Elevation Program (3DEP), in order to increase awareness of its potential technological advancement (USGS, 2017).

In accordance with this movement, schools have begun to implement LiDAR courses in their curricula. Georgia Tech Research Institute was among the first institutions to develop a LiDAR based course (West, Gimmetstad, 2010). Members of the faculty that created the course praised LiDAR as being fairly easy to understand and use with only a basic technological background. (West, Gimmetstad, 2010). Additionally, the Navajo Technical University (NTU) added a course to their Advanced Manufacturing Technologies program. This course, titled "Laser Scanning Methods" seeks to give students access to the fundamentals of LiDAR to capture digital data and apply this data to digital manufacturing (Navajo Technical University, 2018).

This ease of understanding and the wide range of applications that come with LiDAR make it a revolutionary form of technology. However, it is important to note that LiDAR technology is extremely expensive, costing about \$75,000 per ground-based scanner (Wang, Peethambaran, Chen, 2018). While these LiDAR scanners can be used for multiple scans, this significant capital price is not always affordable. Additionally, LiDAR only scans the initial measurements of an object. Additional software is required to create working, 3D digital models of the object (Hu, You, & Neumann, 2003).

## 1.6: Past and Completed Work.

Our project is the continuation of a larger initiative started by University of New Mexico's (UNM) Indigenous Design and Planning Institute (iD+ Pi). Over the past few years, iD+Pi, along with a team of students from Worcester Polytechnic Institute (WPI), have contributed to this project (DeOliveira et al., 2017). In this section, we outline the work done by both of these groups.



### **1.6.1. iD+Pi and WPI.**

iD+Pi was started in an effort to educate people on indigenous architectural design through academic, tribal, and professional processes. Through these processes, iD+Pi integrates indigenous theory into coursework, focusing on the importance of community planning in indigenous architecture. Additionally, iD+Pi provides various networking opportunities and workshops to promote professional development in tribal communities. The applications of these resources comprise a program that aims to give credit to the indigenous people for their architectural contributions as well as encourage more indigenous people to join the architectural field (University of New Mexico, 2016). iArchitecture is the specific initiative that our project continues. The iD+Pi director, Theodore Jojola, expressed the need for this project as people too often relate indigenous architecture to past historical structures, such as teepees (University of New Mexico, 2016).

In 2017, iD+Pi partnered with a team of students from WPI in order to begin the iArchitecture initiative. The combination of their efforts produced LiDAR-scanned point clouds of the Zuni Mission without the roof, a Puebloan church in New Mexico (DeOliveira et al., 2017). By interviewing members of various Puebloan tribes, the team then identified the important architectural characteristics of the buildings being modelled. The team determined that the most important cultural and physical architectural features that link Puebloan architecture and culture are adobe, vigas, and the site orientation. They determined these components based on commonalities within interviews with various Puebloan representatives. Using SketchUp, the team then created two potential exhibit designs depicted in Figures 8 and 9 below (DeOliveira et al., 2017). However, because they did not have access to the complete set of LiDAR data, the exhibit models only represented the potential flow of the exhibit, and the different possible designs.



*Figure 8 - The 2017 Team's First Model  
(DeOliveira et al., 2017)*



*Figure 9 - The 2017 Team's Second Model  
(DeOliveira et al., 2017)*

Since then, iD+Pi has been able to complete the LiDAR scanning process for the Old Zuni Mission in the Zuni Pueblo and the Owe'neh Bupingeh Preservation Project in the Ohkay Owingeh Pueblo. They are currently in the process of scanning the Isleta Head Start building in the Isleta Pueblo. During our project we focused on the Old Zuni Mission to create a partial exhibit prototype. We will recommend our process be replicated for the remaining sites following our departure in an effort to complete the iArchitecture initiative.

The iArchitecture exhibit seeks to synthesize the architecture of six Pueblos: the Zuni, Isleta, Ohkay Owingeh, Pojoaque, Santa Clara, and Acoma. The buildings depicted through this exhibit are outlined in Table 1 below.

**TABLE 1: TABLE OF ARCHITECTURAL SITES**  
(BASED ON INFORMATION FROM DEOLIVEIRA ET AL., 2017)

<b>Pueblo Site</b>	<b>Building</b>	<b>Information</b>
Zuni Pueblo	Old Zuni Mission	<ul style="list-style-type: none"> <li>• Was a religious center, then tourist site, and is now figuring out its future purpose?</li> <li>• Learning from the mistake of renovating the building without a process in the 1960s and now starting a detailed process for renovation</li> <li>• Considering community involvement in the current design and planning process renovation process</li> <li>• Is working with historic preservation partners</li> </ul>
Acoma Pueblo	Sky City Cultural Center and Haak'u Museum	<ul style="list-style-type: none"> <li>• A museum open to the entire public and cultural center open to only members of the Pueblo of Acoma</li> <li>• There was a very heavy level of community involvement in the design and planning process</li> </ul>
Isleta Pueblo	Isleta Head Start Building	<ul style="list-style-type: none"> <li>• Designed through a UNM masters student thesis</li> <li>• Preschool and daycare for supporting native children in need</li> <li>• Provides education for young parents on parenting skills</li> </ul>
Ohkay Owingeh Pueblo	Owe'neh Bupingeh	<ul style="list-style-type: none"> <li>• A plaza filled with personal homes that is also utilized as a community space during holidays</li> <li>• Only open to residents of Ohkay Owingeh</li> <li>• Learned from the mistake of stuccoing the plaza in the 1960s and is now executing a detailed process for renovation</li> <li>• There was a heavy level of community involvement in the design and planning process</li> </ul>
Santa Clara Pueblo	Tessie Naranjo Residence	<ul style="list-style-type: none"> <li>• A personal home passed down the matriarchy with the intention of providing a place of nourishment for all</li> <li>• The home is actively lived in, comfortable, and the design fits traditions of the area</li> <li>• There was no community involvement in the renovation of the home</li> </ul>
Pojoaque Pueblo	Poeh Center	<ul style="list-style-type: none"> <li>• A museum designed to represent the way the community would like to be perceived</li> <li>• Constructed on the 1970s, it is a reconstruction based on various Anasazi ruins throughout the region.</li> <li>• It is the new village center for the Pueblo of Pojoaque.</li> </ul>

These buildings are example of various themes and independent aspects of both traditional and contemporary Puebloan architecture. The iArchitecture exhibit is estimated to be completed in 2021 and will be located in the Indian Pueblo Cultural Center (IPCC).

Thus far, this initiative has incorporated the beginnings of a collaborative exhibition model, which we will continue. This concept will incorporate and apply indigenous perspectives through the exhibition design process (Parezo, 2015). The 2017 IQP team began extensive information gathering and initial exhibit planning. Our team built upon past progress, continuing exhibit development in the form of a culturally appropriate and working interactive prototype.

The purpose of this project was to aid iD+Pi in increasing representation and enhancing the appreciation of Pueblo contributions to contemporary architecture for modern architectural professionals, contemporary society, and Puebloan young adults. Our team first defined learning outcomes for the exhibit and identified the most proficient methods of interactivity. Next, we developed a digital model for the contemporary Puebloan architecture exhibit. Then, we constructed a partial physical prototype of the interactive museum exhibit. Throughout the entire development process, we gathered indigenous feedback from our sponsor. Upon completion of the prototype we obtained feedback from the available WPI college students. This ensured the effectiveness of our end prototype and led the way for the development of a successful final product.

## 2.0 Methodology:

The goal of this project was to aid the University of New Mexico's (UNM) Indigenous Design and Planning Institute (iD+Pi) in increasing the representation and enhancing the appreciation of Puebloan contributions to contemporary architecture by digitally designing and physically creating a working prototype of an interactive museum exhibit.

In an effort to complete this goal, we:

1. Defined universal learning outcomes for the exhibit
2. Developed digital models for the Indian Pueblo Cultural Center (IPCC) architecture exhibit
3. Constructed a working, physical prototype of the interactive museum exhibit
4. Assessed exhibit effectiveness relative to learning outcomes and provided exhibit framework for further development

The combination of efforts between the 2017 IQP team and iD+Pi produced research and survey data from museum visitors and Puebloan representatives. We made our contributions based on this past work. We focused on the technical aspects of achieving iD+Pi's goals using LiDAR scan data to develop a digital model and construct a working interactive prototype. The following sections detail the methodological procedures that we utilized in order to reach the objectives outlined above.

### 2.1 Defined universal learning outcomes for the exhibit.

Our first objective served to define multiple, all-encompassing learning outcomes for iD+Pi's iArchitecture exhibit. These learning goals describe the general knowledge that we intended visitors to gain after experiencing the exhibit. These goals will be reiterated with site-specific examples presented through similar mediums. Our sponsor chose the six sites, described in Table 1, due their communities' willingness to be a part of external data collection. In addition, these sites are culturally important to their respective Pueblos and best represent the traditional Puebloan influences on contemporary Puebloan architecture (iD+Pi, Personal Communication, 2018).

### **2.1.1: Establish Learning Outcomes that Apply to Architectural Sites.**

Through this step, we explicitly defined the learning outcomes of the entire iArchitecture exhibit and how they will be specifically represented through our partial exhibit prototype. These learning outcomes focus on how we want to alter the visitors' perception of Puebloan architecture and the new knowledge they should obtain about the cultural importance of Puebloan architecture. We want the visitors to learn the common physical materials used in contemporary Puebloan architecture, the driving cultural values behind the buildings, and how traditional Puebloan architecture has influenced the local contemporary architectural community. From these, we established three general categories of learning outcomes, each respectively described above: physical, cultural, and influential. This objective allowed us to narrow these categories into specific educational concepts that can be represented through our exhibit and evaluated following exhibit use.

Physical learning outcomes reflect what visitors will learn regarding specific architectural components that are part of Puebloan architecture. To establish the physical learning outcomes, we used the results of the interviews done by last year's IQP team to identify architectural characteristics that Puebloan members feel best represent their culture (DeOliveira et al., 2017). This team interviewed a representative from each of the six architectural sites. From their interviews they determined that the most important architectural components were adobe, wooden ceiling beams called vigas, and site orientation (DeOliveira et al., 2017). Based on technical restrictions, we then defined our method of presentation for the physical learning outcomes as further outlined in section 2.3. We decided to showcase each feature based on whether or not it could be depicted in a way that would require visitors to interact with our model. Then, we utilized literature provided by our sponsor that was previously unavailable to determine additional defining architectural features that conform to the above constraints (Nabokov et al., 1989; Jojola, 1997). We then converted the list of specific features into a learning outcome that could be applied to the various sites. We did this by generalizing the specific features into a measurable learning goal that can be applied to all sites.

Next, we established the cultural and influential learning outcomes. The cultural learning outcome explain what visitors are intended to learn regarding the relationship between Puebloan architecture and their cultural and spiritual beliefs. The influential learning outcome depicts the knowledge visitors should obtain in regard to how Puebloan architecture has changed and

remained the same over time, as well as any cultural implications this may hold. The creation of the cultural and influential learning outcomes was broken up into two steps. First, we met with Scott Evans and Garron Yepa, the director of preservation and cultural projects and an architect, respectively, of Atkin Olshin Schade (AOS) Architects located in Santa Fe. According to Mr. Evans and Mr. Yepa, AOS Architects has extensive experience renovating the homes in the Ohkay Owingeh Pueblo while focusing on the cultural importance of the architecture. We discussed with them the questions they had to ask and the skills they learned in order to ensure their renovations were culturally accurate. We also discussed how these questions have differed amongst various tribes they have worked with. We applied their answers to Puebloan architecture in general in order to determine the learning goals when creating our exhibit prototype. Then, we spoke with them how traditional Puebloan architectural concepts were present in their renovations. We reorganized their answers into general questions that can be asked in regard to each specific Puebloan building that will be depicted in the exhibit. The questions determined from this meeting served as the guidelines for determining future cultural and influential learning outcomes.

The second step of this process was to confirm that our questions are factual and intuitive with our sponsor. Since iD+Pi will use these learning outcomes in the future and has experience with Puebloan culture, it is important that they review our learning goals prior to us finalizing them. In addition, we went to Zuni Pueblo and spoke with Tom Kennedy, Norman Coeoyate, and Wells Mahkee, respectively the Zuni Tourism Director, the former Zuni Governor, and a Zuni Tourism Board Member to further confirm the accuracy of our questions. There, we also discussed further information, such as Zuni culture and history that could be incorporated into our final deliverables.

In order to contextualize the learning outcomes to our exhibit prototype, we created a written document describing how the Old Zuni Mission and the Isleta Head Start Building illustrate the learning outcomes. Additionally, we created a framework where iD+Pi can populate the remaining sites' respective alignment with the learning outcomes. This document will help define and organize how each building contributes to the overall learning outcomes of the exhibit.

Through this objective we were able to convert physical, cultural, and influential architectural components into specific educational objectives.

## 2.2 Developed digital models for the IPCC architecture exhibit.

Our second objective was the development of 3D digital exhibit models for the selected contemporary Puebloan buildings. In this section, we detail a model creation process that applied for the Old Zuni Mission, spanning the conversion of LiDAR scan data to usable and optimized digital model geometry. Depending on the multimedia we used, the model primarily took the form of either an entire architectural site or as specific building features, both of which share identical creation methods with a difference in scale. Exact LiDAR measurements and on-site photographic comparisons were then used to compare the geometric results to their respective physical counterparts to determine model accuracy.

### **2.2.1 Creation Procedure for Usable 3D Model Geometry.**

Our team's multimedia exhibit prototype utilized a digital 3D model of the Old Zuni Mission. To ensure this model accurately reflected the architectural site, LiDAR scan data was the foundation for the creation process. Light Detection and Ranging (LiDAR) technology refers to the usage of pulsating lasers to measure the depths of physical object. When the LiDAR scan's point clouds are viewed together, they recreate the building's exact geometry in digital space (Hu, You, & Neumann, 2003).

Our sponsor's collaborators at Navajo Technical University (NTU) provided us with the point-cloud data of the Old Zuni Mission when we arrived in Santa Fe. While we were in Santa Fe, iD+Pi and NTU were in the process of completing the scans for the Isleta Head Start Building and the roof of the Old Zuni Mission. We assisted them in gathering these scans.

After the point cloud data was obtained, our team processed the data using LiDAR compatible programs, FARO Scene, Autodesk ReCap 360, and GeoMagic X Design, to create the first initial model. FARO Scene refined the raw point-cloud data through a process called indexing to unify the individual point clouds of each scanner and optimize point geometry into a usable 3D image of a structure. We then took precise measurements in ReCap 360 to begin a process known as building information modeling (BIM)--the digital depiction of a building's physical and functional attributes (Brightman, 2013). Through this process, we were able to define the digital model into its fundamental shapes in SolidWorks for 3D printing purposes. In addition, we converted the LiDAR scans from a point cloud into an optimized mesh using GeoMagic X Design. Meshes are truncated 3D model alternatives that use fewer points and planes to approximate point-clouds at the cost of losing surface color detail in addition to up to



75% of the geometric resolution. We utilized meshes as an experimental way to highlight isolated single architectural features. At this stage, we converted the mesh model from a file of millions of data points to a few thousand. This allowed us to create real-time detailed digital interactions and virtual fly-throughs with minimal computational power. (Wang, et.al, 2018; Kee, 2014). We then created the flythrough in order to depict the cultural learning outcomes of our exhibit. This allowed visitors to see the Zuni Mission virtually and gain a deeper understanding of its components.

### **2.2.2 Confirming Accuracy of Model Scans to Physical Architecture.**

We recognized that by optimizing and translating the LiDAR data into new 3D forms, some processes prioritized model simplicity over detailed geometric accuracy, and vice versa. We avoided gaps in site representation by displaying both a simplified geometrically accurate model for scale in SolidWorks and a detail-isolated mesh model for key building features. Our Solidworks model utilized AutoDesk ReCap 360's exact distance measurements pulled from the raw point-cloud data, ensuring the overall building proportions are representative of the actual site. Likewise, once a 3D mesh was completed, we used ReCap 360's measurements to confirm that the mesh optimization did not compromise the feature dimensions.

Then, our team compared site photographs and their real-world location relative to the Zuni Pueblo building itself. We went to the Old Zuni Mission and captured images that focused on key dimensions and unique features to help us accurately represent building features like texture, color, and scale. Next, we visually compared these building photos with their respective SolidWorks and mesh model and approximated the software's view orientation relative to the building to match the orientation of the physical camera location. An example of this process can be seen in Figure 10 from a LiDAR structure study in 2015.



*Figure 10 - Reality Versus LiDAR Comparison*

(GeoPro Consultants, 2015)

This visual comparison acted as a proportional analysis to validate the geometric accuracy of our modeling procedure (Pedram, Becerik-Gerber Burcin, & Lucio, 2015). For our comparison, we visually examined these images to find any significant photographic discrepancies. Any discrepancies we found are later reported in Section 3.2. After the digital model was declared accurate by our team and iD+Pi, it was then ready to be incorporated into the multimedia form of our exhibit prototypes.

### 2.3 Constructed a working, physical prototype of the interactive museum exhibit.

Once a digital model was created, we further developed it into an interactive physical exhibit prototype. The form of the exhibit prototype depended heavily on the specifications of our sponsor and our learning outcomes. These learning outcomes were divided among our methods of interactivity. The multimedia format we used for the partial prototype of the interactive museum exhibit came in three parts: an interactive physical prototype and two different digital mediums. For these three parts of the interactive exhibit, our sponsor procured for us the use of a 3D printer, access to an iPad, and access to a QOMO Journey 13 Series 65” touch table. For this reason, these became the three main interactive media for our exhibit.

#### **2.3.1 Assigning Learning Outcomes to and Creating the Physical Model and Digital Media.**

We created an interactive prototype by developing a two-part digital medium accompanied by a kinesthetic experience for the user. Due to time constraints and the wishes of our sponsor, these were prototypes that our sponsor will be able to use to show to investors, therefore they were not representative of a final finished product, but of a thorough and polished partial example model. Our focus was on the Old Zuni Mission, therefore all elements outlined in this section were applied to the prototype for that site.

First, we created a list of all the information to be displayed through the various methods of interactivity. From there, we categorized this information based on the feasibility of representation through each device in conjunction with the device’s capabilities.

The physical prototype was developed using SolidWorks, which was the tool used to create 3D printable files. We then printed these models with the use of the provided 3D printer. Due to the interactive, analog potential of 3D printing, we modeled the specific features of Pueblo architecture as part of a 3D printed model of the Old Zuni Mission. Once printing was

complete, we painted the model with a mixture of paint and texturing element to resemble the adobe used on the real building. We confirmed our choice of color and texture with a Zuni Puebloan representative and our sponsor. Buttons were then added in order to give the exhibit added interactivity. These buttons took the form of touch sensors and displayed a visual indication of the architectural feature when touched.

The digital medium portion of this exhibit took place in two parts, a touch table and an iPad. A touch table is a uniquely interactive tool that is able manage more than five touch points. A touch point is a way of communicating commands to the touch table, and is created when a finger or, for some models, any object comes in contact with the screen. Most touch tables have the capability to understand specific touch point patterns meaning that it can be programmed to trigger specific commands based on specific patterns. However, when more objects are touching the screen than the device can manage, the excess objects are not recognized. Common touch tables can handle up to eighty touchpoints (IDEUM, personal communication, September 6, 2018). If multiple people are using the touch table with both hands and recognized devices, though, these points can be used up very quickly. We took these factors into consideration when designing the exhibit. Additionally, we used the iPad in order to further present information regarding the site. iPads are capable of presenting information to more than one person, but are constrained to five or six touch points, which restricts the device to one user at a time.

The content depicted in each respective multimedia was decided based on the learning outcomes that would best be depicted. For example, physical features are most clearly represented on a 3D model. Additionally, the individualistic aspects are best depicted on the iPad, because each site will have its own dedicated iPad. The common aspects of architecture are best shown on a communal device, such as the touch table. The formatting and color schemes for the touch table were based on the most common Pueblo tribal colors and iPad color schemes are based on the six traditional Zuni Pueblo colors.

The completed exhibit will house five other sites besides the Zuni Mission. We expect that each will have its own 3D printed model and iPad, and all six sites will share a single touch table. In order to decide how these interactive media will be positioned in the exhibit we primarily considered the movement of guests throughout the exhibit. When recommending designs for exhibit flow, we split up the information throughout all interactive means to limit crowding on a single device.

### **2.3.2 Conforming to Prototype Requirements and Constraints.**

Our prototype design process was informed by the requirements and constraints posed by our sponsor and the IPCC. This included trying to attract more children and families, limited available exhibit space, and ensuring that the exhibit could be a shared, communal experience among visitors (DeOliveira et al., 2017).

In order to meet these constraints, we first divided the exhibit content into two levels of learning. The first level focused on incorporating child-friendly information and interactivity. This was meant to introduce the visitor to contemporary Puebloan architecture and provide them with an interactive and exciting foundational knowledge of the subject. The second level provided additional information to visitors hoping to become more educated in the field.

Next, we designed the exhibit in a way that will facilitate an open and communal exhibit flow while taking up an appropriate amount of space. In order to do this, we combined the recommended exhibit designs created by last year's IQP team. Since they incorporated the size of the available exhibit space into their designs, they served as our main guide for the prototype. To ensure a shared experience, we designed the multimedia experiences in a way that dispersed the information and interactivity throughout the site. This will allow multiple visitors to view the various exhibit pieces together.

## **2.4 Assessed exhibit effectiveness relative to learning outcomes and provided exhibit framework for further development.**

Our fourth objective served to determine the exhibit's effectiveness in a guided survey. The main purpose for conducting this assessment was to gain insight on what people learned from the interactive exhibit prototype and if they matched our learning goals. For this reason, we organized a guided survey, with college students as our subjects.

### **2.4.1 Guided Survey with College Students**

This preliminary survey was intended to determine how well the exhibit educated the audience on our learning outcomes and the effectiveness of the 3D models and digital interactive portions of the exhibit. We used the results from this survey to make suggestions on how to increase the effectiveness of the exhibit for our sponsor to incorporate into their finalized version.

We initially planned to carry out two focus groups, one with Puebloan representatives and the other with IPCC visitors. On-site constraints prevented us from conducting prototype tests with these target audiences, leading us to the current method of conducting a guided survey. We first arranged the prototype exhibit in a common area at the Fort Marcy Hotel Suites in Santa Fe, NM. We used an iPad for the tablet interactive portion and substituted a standard 42-inch television connected to a laptop computer for the touch table. We then invited a group of eleven college students divided into groups of five or six to explore the prototype without guidance. We chose a small group of college students from WPI who were being housed in Santa Fe at the time. These students were used as a preliminary indication of our prototype's ability to portray our learning outcomes.

We recorded how long each subject spent interacting with the exhibit in order to make suggestions for the future focus groups. Afterwards we asked several guiding questions in order to determine which aspects of our exhibit were strongest and weakest, listed in Appendix F. The purpose of the first few questions was to gauge test subjects' understanding of our main exhibit learning outcomes. The next question aimed to determine if the digital interfaces and physical models were intuitive enough for the average college student to use completely on their own. This was important for us to gauge the clarity of our prototype because, for the actual exhibit, museum visitors will have to learn on their own. With the last questions, we were attempting to determine to what extent the test subjects' understanding of Puebloan architecture and its cultural connotations had grown. This was to determine if visitors would indeed leave the exhibit with an understanding of the buildings features and that they were informed by Zuni's specific history and culture, consistent with our learning outcomes for the exhibit.

While some questions required concise answers, others were open for the participant to expand on their reasoning through short group discussions in order to get comprehensive feedback. On the other hand, the results of purely factual answers, such as correctly identifying or defining the purpose of certain architectural features, were displayed in bar graphs. For these factual questions, we used an average correctness baseline of 75% to classify whether visitors adequately learned the main exhibit learning outcomes. If a particular visitor achieves 75% of our learning outcomes, he or she has obtained the intended amount of knowledge from the exhibit. We conducted this guided survey in week six, after we had a sufficiently functioning

prototype, and made recommendations based on the outcome for our sponsors to incorporate into the final project.

#### **2.4.2 Documentation and Framework for Exhibition Completion**

Since the interactive exhibit prototype we created is only one piece of the final iD+Pi exhibit, we additionally provided a guiding document detailing the overall procedures we used with the Old Zuni Mission prototype. This document was broken into three sections each detailing a different part of our process.

The first section describes the various processes we used in the technical design and creation of our prototype. This included a list of programs we used to process the LiDAR data from point-cloud format to 3D printable model and interactive mesh model formats, as well as information on program license costs and hardware requirements. This section also discusses the process of representing the combined models and interpretive information on the digital mediums.

The second section detailed a general template for determining site-specific content for the remaining exhibit. We used a variety of mediums and methods of interactivity to represent the three general learning outcome categories. This section outlined the educational purpose of each of these display methods as well as explaining what the exhibit's learning outcomes are. Once again, it included the costs and hardware requirements for each medium.

The third and final section went over specifics for each of the architectural sites. Since the Old Zuni Mission had a completed prototype, its portion first detailed the physical, cultural, and influential learning outcomes previously established. Additionally, it explained how these were specifically depicted through the various exhibit mediums. For the remaining sites, we included the learning outcomes in framework form as discussed in section 2.1.

### **3.0 Results:**

The following chapter outlines the results from our four objectives. From the first objective we determined how to present the cultural beliefs embedded in the architecture of the Zuni Pueblo in the form of exhibit learning goals. Throughout our second objective, we learned the programs as well as their respective costs and capabilities needed to convert point clouds to a manufacturable model. While constructing our prototype we learned the most effective mediums to present the various exhibit components, how to comply with their corresponding constraints, and how to disperse them in a fluid manner. Lastly, we report the results of our tests to evaluate the effectiveness of our exhibit learning outcomes. The combination of these results contributed to the development of our partial prototype and exhibit framework.

#### **3.1 Defined universal learning outcomes for the exhibit.**

The results of this objective define the specific physical, cultural, and influential learning outcomes of the iArchitecture exhibit in general and how they are contextualized in the Old Zuni Mission and Isleta Head Start Building.

##### **3.1.1: Establish Learning Outcomes that Apply to Architectural Sites.**

In this section we will describe our results when determining the general learning outcomes.

##### **Physical Learning Outcomes:**

From last year's report, we determined that important Puebloan Architectural features include adobe, latillas, vigas, and site orientation. Since site orientation could not be depicted through a 3D printed model of the Old Zuni Mission building, we decided to highlight adobe, latillas, and vigas. Our additional readings added canales, ramadas, niches, and splash boards to this list. Using this list, we created a physical learning outcome for our exhibit prototype.

*Visitors will be able to identify specific architectural components commonly represented within Puebloan architecture.*

This learning outcome follows from the observation that many Puebloan buildings share common features. However, while many Puebloan buildings share one or more of those architectural elements, we also wished to emphasize the uniqueness of these features on each

building. Typically, each different tribe constructs the features from different materials and uses them for a different architectural purpose, usually structural or aesthetic. From this concept, we established a second physical learning outcome.

*Visitors will be able to identify the composition, uniqueness, and architectural purpose for each specific site's physical features outlined in the 3D model.*

### **Cultural Learning Outcome:**

Following our discussion with Shawn Evans and Garron Yepa of AOS Architects, we learned that architects must consider the answers to the following questions when ensuring cultural accuracy through architecture (AOS Architects, Personal Communications, August 2018):

- What is the idea of this building and the space around it?
  - This question refers to how the specific building is related to Puebloan culture. Typically, the space around the building holds just as much importance as the building itself, often being the space used for cultural events. Additionally, this question seeks to determine how the building itself is a depiction of the local traditions and values.
- How do the tribal values intersect with the architecture?
  - This question seeks to identify the cultural meanings behind specific Puebloan architectural characteristics and how they may be informed by tribal values. The presence of such architectural characteristics will be more justified and contextualized by connecting the driving values behind each characteristic.
- Is the Puebloan community more respectful of the world or local view?
  - This question refers to whether or not the respective Puebloan architecture focuses more on depicting local cultural traditions or more modernized, worldly traditions. For example, the murals in the Old Zuni Mission depict local kachinas, Zuni deities. When Christianity-themed images were added to the Mission, they were removed. This makes the Old Zuni Mission more respectful of the local



view, as they focus more on representing their spirituality rather than other spiritualities in the world.

- Are there any interior images or objects that represent cultural history, values, or change?
  - This question considers the importance of interior decoration on the cultural representation of a piece of architecture. It gauges the importance of replicating interior features with questionable architectural purpose with the same detail as main architectural components. When being representative of cultural beliefs, any interior imagery is commonly just as important as the building it is within.

The answers to these questions provide a broader understanding of the cultural influence behind Puebloan architecture. Additionally, the answers provide deeper insight into the spiritual importance Puebloan architectural components hold. With these questions, we established common themes and main points from each of them. We then combined these into a single statement that reflects the cultural implications provoked by these questions. We established a learning outcome related to cultural and spiritual architectural features.

*Visitors will be able to recognize that and explain how Puebloan architecture often embodies community, spirituality, and reactive beliefs and values.*

This learning outcomes applies to both levels of learning previously discussed in section 2.3.2. It is intended that those in the lower level will be able to recognize the cultural importance of Puebloan architecture while those in the upper level will be able to explain how culture is depicted through each respective architectural site. Additionally, this learning outcome relates the spirituality of the community to the physical design of the architectural site. Typically, the features that make up a building hold importance in regard to tribal beliefs. For example, the north and south wall in the Old Zuni Mission face the direction of their respective solstices. In Zuni culture, the north is associated with the winter solstice and the south represents the summer solstice because of the weather cycle of the upper and lower hemisphere. This carries great significance since during each of these solstices, Zuni religion identifies these as a time when the kachinas, which are important Zuni deities, bless the homes and bring luck for the future season.

(iD+Pi, 2018; AOS Architects, August 2018; Tom Kennedy, September 2018, Personal Communications). The reactive beliefs and values represent the Puebloan reaction to modernity and how it impacts their culture. For example, the aforementioned kachinas were depicted within the Old Zuni Mission through large murals on the north and south walls in the 1970s renovation. An additional mural was later added, merging Christian symbolism with kachina imagery, and was later taken down due to community disapproval of overbearing external influence.

### **Influential Learning Outcome:**

The influential learning outcome refers to how traditional Puebloan architecture has impacted contemporary architecture. Although building specifics, such as material, may have changed, it is common that some aspects of the building have remained unjaded by time. In addition, AOS Architects informed us how traditional concepts of Puebloan architecture are presented within new site renovations. Through this interview, we arrived at the following questions focusing on contemporary Puebloan architecture and the traditional architectural styles that influenced it:

- What is the purpose of physical architectural features for this site?
  - This question refers to the purpose of each architectural feature. Depending on the tribe, this may refer to a cultural purpose, an architectural purpose, an aesthetic purpose, or some combination of these.
- What is the composition and creation process of physical architectural features for this site? How and why is it unique?
  - This question seeks to identify the unique traditions behind the creation of Puebloan architectural components. It serves to offer further insight into the complex creation methods behind each architectural characteristic and how they may change between Puebloan communities. For example, the Old Zuni Mission uses vigas made out of pine for the structural purpose of supporting the roof. This is more reflective of traditional Zuni architecture. The Isleta Head Start building uses steel vigas for aesthetic purposes. Each of these buildings have the same feature, but make it in a different way and use it for a different purpose.

With these questions, we analyzed research on the Old Zuni Mission, the Isleta Head Start, and the remaining sites to find a broader theme. Then, we combined the questions and

reduced them into a single statement that encapsulates their general takeaways. From here, we determined a learning outcome that highlights this influence:

*Visitors will be able to recognize that and explain how contemporary Puebloan architecture has a base in traditional design but has changed as modernized worldviews become more prevalent.*

This learning outcomes applies to both levels of learning previously discussed in section 2.3.2. It is intended that those in the lower level will be able to recognize the cultural importance of Puebloan architecture while those in the upper level will be able to explain the relation. It also serves to relate the similarities and explain the differences as an architectural site is changed over time. For example, the Zuni mission has remained in the same relative location, the center, of the community boundaries since its creation in 1629. Despite this, its primary material has changes from real adobe, to stucco cement. Additionally, the building dimensions have gotten smaller over time as a result of outside contracting (AOS Architects and Zuni Tourist Director, Personal Communications, September 2018).

#### **Learning Outcome Illustrations for each Site:**

In order to focus the learning outcomes on the sites we worked with directly, we created a document detailing how the learning outcomes are represented through the Old Zuni Mission and the Isleta Head Start Building. The completed document can be found in Appendix B.

To establish the physical learning outcome illustrations for the Zuni Mission we applied the general list to the LiDAR scans provided by UNM. The purpose of this was to see which of the pertinent physical features are applicable to this site. From the scans we determined that the Old Zuni Mission contains vigas, latillas, canales, and adobe. Specifically regarding the Old Zuni Mission, we determined these architectural features had unique aspects, outlined in section 3.3 and Appendix D. To establish the physical learning outcome illustrations for the Isleta Head Start Building, we went to the building to assist with the LiDAR scans occurring there on September 12, 2018. While at the building, we referenced our general list and applied it to the building's physical components. We noted that a modern adobe-like material and vigas were used in the building's construction. The uniqueness of these features is outlined in section 3.3 and Appendix D.

In order to establish cultural learning outcome illustrations for the Old Zuni Mission we completed individual research and confirmed our findings with the former governor of the Zuni Pueblo, Norman Coeoyate. The purpose of this dialogue was to gain knowledge on the values and culture of the Zuni people in order to see how they were applied to the architecture and design of the Zuni Mission. This research was converted into the following learning outcome illustrations (Zuni Tourist Director, Personal Communication, September 2018). The purpose of the below list is to explain how the Old Zuni Mission specifically depicts the cultural learning outcome. Essentially, it outlines all the possible features visitors could use to relate this site to the intended outcome:

- The Zuni Mission is the center of the Zuni Pueblo. This holds cultural, spiritual, and symbolic significance to the tribe as the physical centers often reflect the spiritual centers
- The space immediately around the Mission holds spiritual importance as it is representative of the life and memories of the people that live there
- Puebloan architecture is reactive to its environment rather than static.
  - This is represented through the murals as they show the Puebloan experience with Christianity and the Puebloan response to social change. The Mission itself was deconsecrated by priests due to them feeling overwhelmed by the murals themselves, depicting Zuni spirituality marching against the Christian altar (Zuni Tourist Director, Personal Communication, September 21, 2018).
- The Mission is considered a sacred ancestral site as members of the Pueblo are buried underneath.

In order to establish cultural learning outcome applications for the Isleta Head Start Building we spoke to the Head Administrator of the building and Professor Jojola. We included Professor Jojola in our research because he is from the Isleta Pueblo and one of his prior graduate students designed the building. The purpose of this communication was to gain knowledge on the values and culture of the Isleta people in order to see how they were applied to the architecture and design of the Isleta Head Start Building. We converted this research into the following learning outcome illustrations:

- The Isleta Head Start Building's center room and corridor design are influenced by solstice patterns collinearly.

- The main foyer in the building is a circular shape with the four main hallways extending from it. This is important as the main hallways were oriented in different directions depending on the position of sunlight shining through the central skylight on each solstice and equinox. During each solstice, the sun's respective position shines through the main central skylight in specific locations.
- The Isleta Head Start has rounded hallways to overcome institutionalized feel of typical architecture.
  - The main classroom hallway is curved around the building's circumference, separating the hallway feel from that of a large institutional building with long straight hallways.
- The grade level hallways of the Isleta Head Start spatially move counter-clockwise to represent migration of the Isleta.
  - As children progress through the grade-level classrooms, they move through the building counter-clock representing the ancestral counterclockwise growth of the Isleta Pueblo through time.
- The Isleta Head Start center room floor design has the color scheme of a little island to represent the meaning of Isleta – which is “Little Island”.
  - The central room's floor has a counter-clockwise spiral pattern with blue and yellow colors, loosely depicting a small island.

To establish influential learning outcome illustrations for the Old Zuni Mission, we consulted AOS Architects and their process for depicting architecture in Ohkay Owingeh. The purpose of this discussion was to understand how the physical features were informed by and reactive to external influences. We learned the importance of the Old Zuni Mission's central location over time and its consistent styles through renovations. These illustrations are detailed below (Tom Kennedy, Personal Communication, September 2018). Again, the purpose of this list is to identify the qualities and features of the Old Zuni Mission that serve to represent the general learning outcomes.

- The Old Zuni Mission stayed relatively in the center of the Pueblo throughout its history

- In Zuni culture, the physical centers often represent spiritual centers as well. Although it is no longer used as a church, the Old Zuni Mission still symbolizes the spiritual center of Zuni beliefs.
- The style of the Mission stayed the same through renovations and material changes
  - Throughout renovations, the Old Zuni mission went from being constructed of adobe to having a stucco cement outer layer. Additionally, the dimensions have grown smaller over time. Despite this, the general shape and location of the Zuni mission has stayed the same.
- The contemporary model of the Old Zuni Mission has its basis in traditional Puebloan architecture
  - The alterations performed depict the Zuni’s focus on preserving their traditional architecture through modernization and renovation.

We did not create specific influential learning outcomes for the Isleta Head Start Building as we did not have sufficient information and contacts regarding how this site has changed over time.

By providing examples of learning outcome illustrations for the Old Zuni Mission and partially for the Isleta Head Start, our sponsor will have this framework to continue this process for the remaining four sites. The written document that has been provided to our sponsor with all the above information can be found in Appendix B.

### 3.2 Developed digital models for the IPCC architecture exhibit

This section documents the specific results used to process the raw LiDAR point-cloud data of the Old Zuni Mission into optimized forms. This includes information on the programs we used, their respective costs and licenses and equipment requirements.

#### **3.2.1 Created Procedure for Usable 3D Model Geometry.**

##### **LiDAR Processing:**

Our sponsor provided us a single unorganized point-cloud file (.pts). We removed scan data beyond the Old Zuni Mission building and noise caused by reflective surfaces, the results of which are seen in Figures 11 and 12. Through this initial process, we reduced the number of points from about 1.3 billion to 173 million.

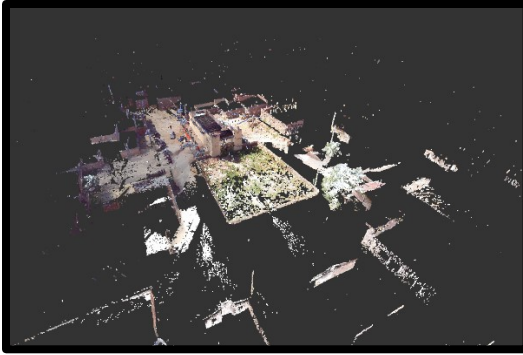


Figure 11- Original Point-Cloud Data



Figure 12 - Cleaned Point-Cloud

Once the point cloud was reduced to only the Old Zuni Mission site itself, we recorded the measurements seen in Figure 13 of building structures with the distance tool in Autodesk Recap 360.

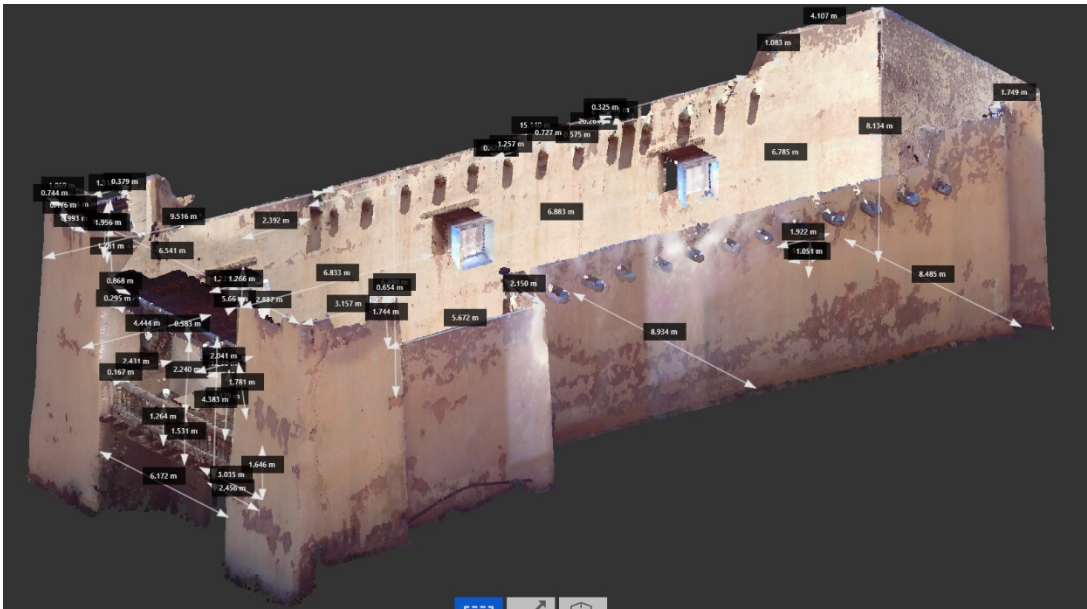


Figure 13: Point-cloud Measurements

### SolidWorks 3D Model:

We used the measurements recorded in Recap 360 to convert the LiDAR point-cloud to SolidWorks. In the process, we simplified some of the measurements and site features. For example, due to sediment build up on the north wall of the building, shown in Figure 14, the LiDAR imaging shows the bottom of the building as incomplete and curved even though the actual measurements were hidden by dirt.

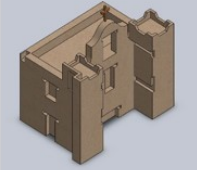


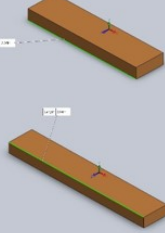
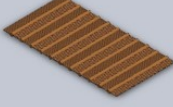


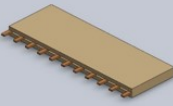

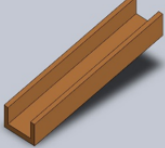
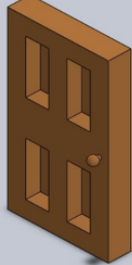
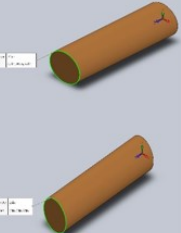



*Figure 14: Obscured North wall LiDAR Data*

This is not ideal for 3D modelling or printing, which required us to use various measurements as the baseline. It is general practice in 3D modeling to use the largest dimensions as the defining features. As a result, we broke the model into visual components that would be easy to 3D print. Based on the natural corners and shapes of the Zuni Mission we decided to model the Old Zuni Mission in sections depicted in the below table.



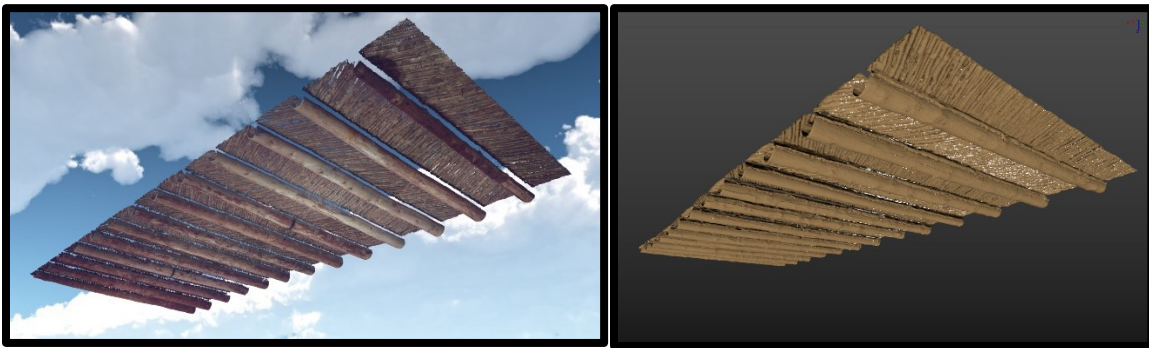
**TABLE 2: MODEL VISUAL COMPONENTS**

Part Name	3D Digital Model	Part Name	3D Digital Model
Old Zuni Mission Front		Window	
Old Zuni Mission Back		Wood Above the Window (Small / Large)	
Large <u>Viga</u> and Latilla Roof		Upper Window Trim	
Small <u>Viga</u> and Latilla Roof		Deck	
Railing		<u>Canale</u>	
Door		<u>Vigas</u> (Regular / Button)	
		Tangible	

Printing these pieces separately increased the ease of printing as less supporting material was required. Additionally, these sections have varying textures, materials, and colors. Therefore, we decided that the final model would be more authentic if we painted different components separately.

### **Mesh Model:**

After the SolidWorks model was ready for printing, we isolated the point-cloud data further to only include one key feature, the main vigas and latillas, seen in Figure 15. By using GeoMagic X Design, we converted the point-cloud into a mesh, reducing the file size from 11 million points to 2.4 million vertices, the mesh file type equivalent of points, shown in Figure 16. The mesh was then imported into a touch-table app suite for virtual interactivity and display, detailed more in Section 3.3.



*Figure 15 - LiDAR Image of Zuni Vigas & Latillas*      *Figure 16 - Mesh Render of Zuni Vigas & Latillas*

### **3.2.2 Confirmed Accuracy of Model Scans to Physical Architecture**

In this section, we validated our optimized LiDAR models by visually comparing original site photographs with our digital representations. As seen in Figures 17, 18, 19, and 20, we found there was little dimensional and scalar variation. The only variation was that the ground LiDAR scanner could not capture the cross structure on the front roof as our sponsor did not provide us LiDAR data for the actual roof.



Figure 17 - Photo of Old Zuni Mission S-E View



Figure 18 - LiDAR image of Old Zuni Mission S-E View



Figure 19 - Photo of Old Zuni Mission N-E View



Figure 20 - LiDAR image of Old Zuni Mission N-E View

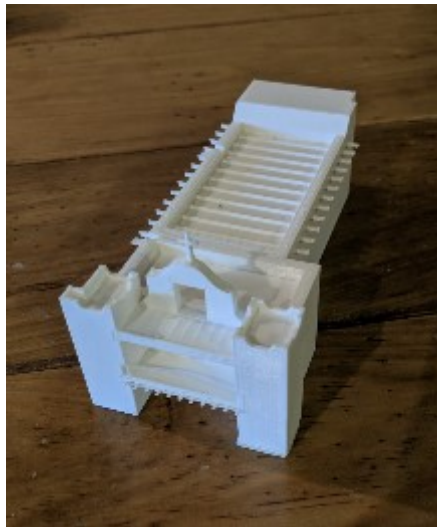
From this comparison, we conclude that our LiDAR data accurately reflects the physical features of the Old Zuni Mission. Because we used Autodesk ReCap 360's exact distance measurement tools based on the LiDAR point cloud, seen in Figure 13, our 3D printed CAD model is also dimensionally accurate. Conversely, our mesh model also remains accurate since the conversion process from LiDAR to mesh involved no dimensional or scalar modifications, visually confirmed in Figures 15 and 16.

### 3.3 Constructed a working, physical prototype of the interactive museum exhibit.

This section documents the results of our physical and digital medium prototypes. This includes the learning outcomes assigned to the different media, the constraints we conformed to, and the final design for the flow of the exhibit. The last portion of this section reviews our recommended exhibit flow.

### 3.3.1 Assigned Learning Outcomes to and Creating the Physical Model and Digital Media 3D Printed Model:

We created two different 3D models. The first was approximately a 200:1 scale. This was used as a “tangible” to be placed on the touch table to bring up site specific information. A tangible is an item that can be recognized by the touch table once placed on the screen. Our tangible can be seen in Figure 21 below. The second is an 80:1 scale model that is used to portray the physical learning outcome regarding identification of common architectural features.

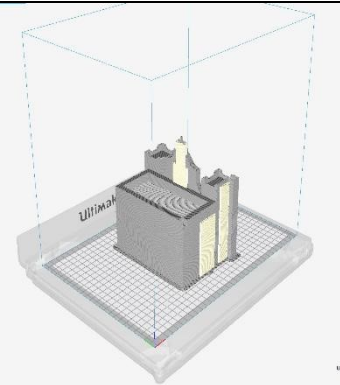
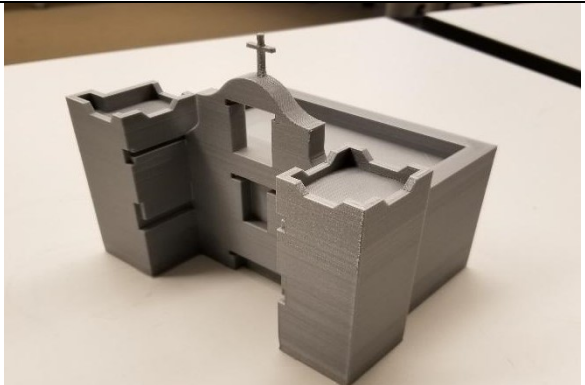
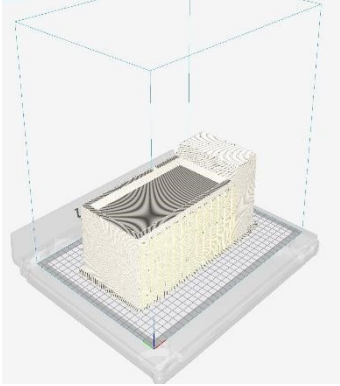
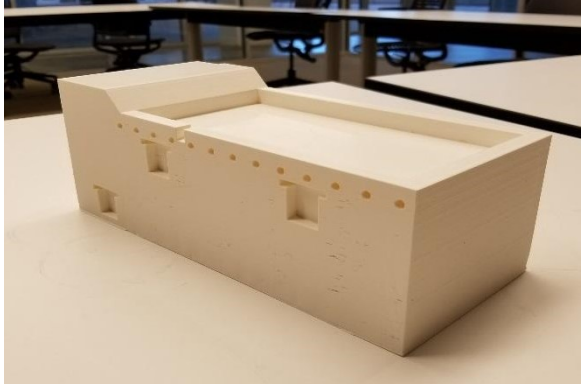
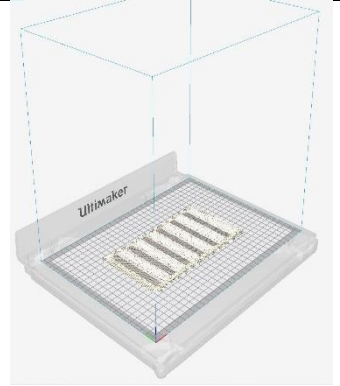
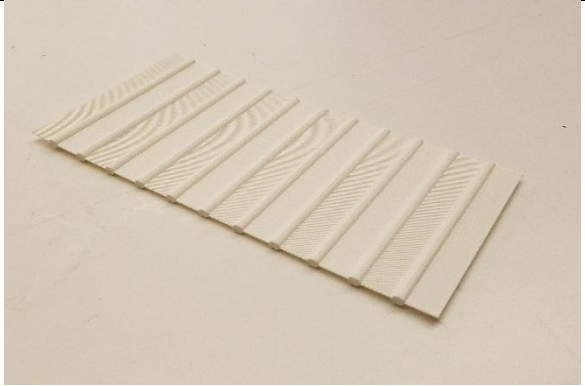


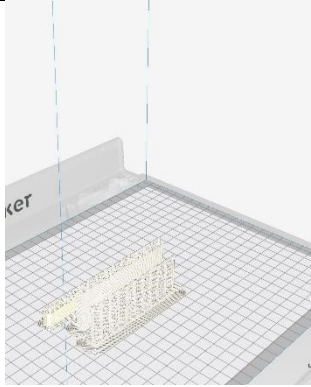
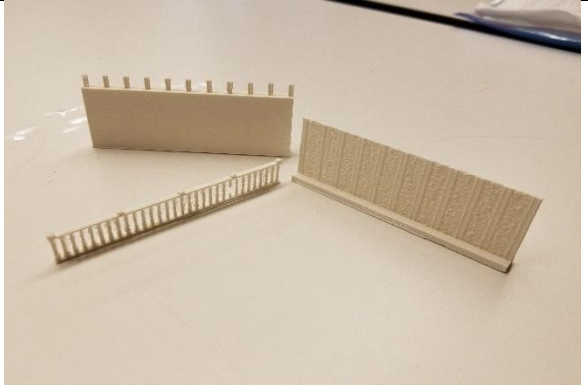
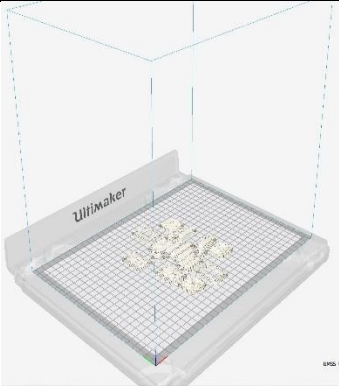
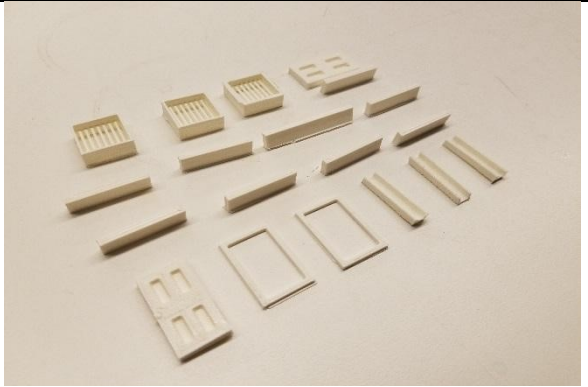
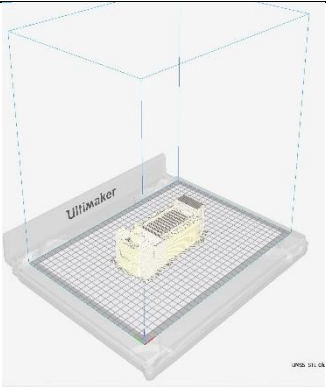
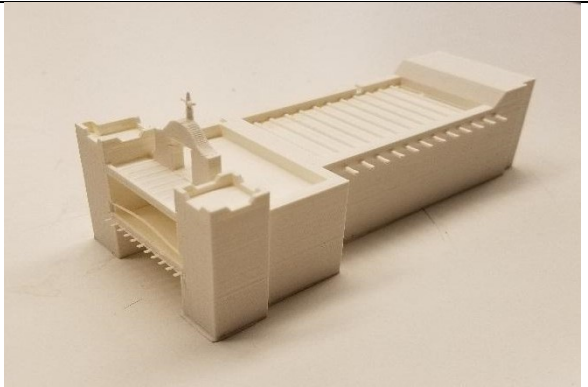
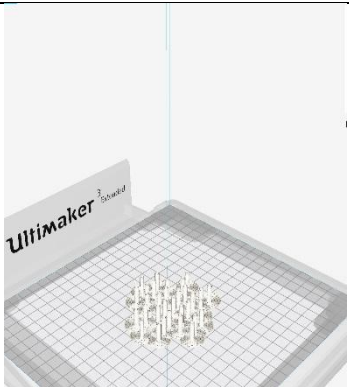
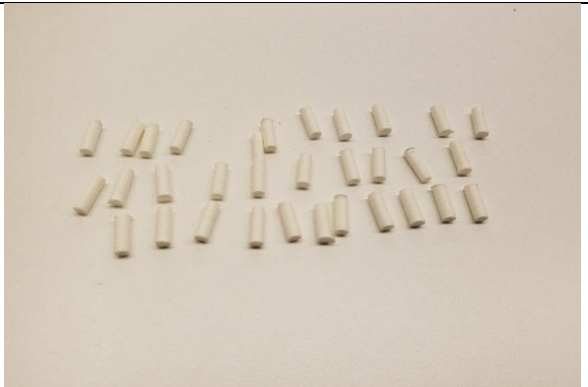
*Figure 21 - Old Zuni Mission 3D Printed Tangible*

In order to increase ease of printing, we divided the necessary components into six different prints. The models were converted to files compatible with 3D printing (.stl) using SolidWorks and imported into Cura, the 3D printing software. Each print was done using PLA material with two different printers. The Ultimaker S<sup>5</sup> was used for the first five larger prints while the Ultimaker 3 Extended was used for the small viga print. The front and back of the Old Zuni Mission were printed with 0.15mm layer heights to increase accuracy while the rest of the prints had 0.2mm layer heights. The support material on all prints was polyvinyl alcohol (commonly referred to as natural PVA), a substance that is water soluble. When the prints were completed, we soaked them in water to remove the support material. This information is detailed in Table 3 below. The pieces produced by each print are included. Most prints were done in white, however, the front of the Old Zuni Mission had to be done in silver filament because of limited availability of white material. A larger depiction of the 3D printing software images can be found in Appendix J.



**TABLE 3: 3D MODELS AND PRINTED PIECES**

Print Number: Parts Included	3D Model in Cura before Printing	3D Printed Pieces after Printing
<p><b>Ultimaker S<sup>5</sup>:</b></p> <p>1: Old Zuni Mission Front</p>		
<p>2: Old Zuni Mission Back</p>		
<p>3: Large Viga and Latilla Roof</p>		

<p>4: Small Viga and Latilla Roof, Deck, and Railing</p>		
<p>5: Canales (x3), Doors (x2), Windows (x3), Small Window Wood (x8), Large Window Wood (x1), and Upper Window Trim (x2)</p>		
<p>6: Tangible</p>		
<p><b>Ultimaker 3 Extended:</b></p>		
<p>1: Regular Vigas (x30) and Button Vigas (x2)</p>		

We then painted the printed model with a mixture of Mauve Dust and Maroon-colored acrylic paint and sand. Per the request of Tom Kennedy from the Zuni Pueblo, the model was painted to look more like the original adobe used during construction. As a result of this, sand was mixed with the paint for texturing purposes while omitting wall cracks or rain damage for a cosmetic final model.

The physical architectural learning outcome--*visitors will be able to identify specific architectural components commonly represented within Puebloan architecture*--was assigned to the 3D printed model because of the user's ability to see and touch the different elements on a miniaturized model. This is also due to the fact that the 3D printed model would better suit straightforward learning outcomes rather than ones that require further explanation.









Each of the four physical learning outcome illustrations for the Zuni Mission (the adobe, vigas, latillas, and canales) are illustrated with interactive components. Specifically, visitors will be able to push in one viga and one canale and this will trigger a light next to the name of the feature on a wooden plate. Likewise, there will be a button on the adobe, and the latilla roof will be able to be pushed down. This allows the user to associate the feature with the name of the architectural element. An image of the full model and the locations of the four buttons can be seen in Figure 22. A table of the buttons pressed and the name of their corresponding architectural element that will light up can be seen in the Table 4 below. For the circuit a 9V battery powers four 6mm x 6mm x 3.1mm push buttons that were placed in the 3D printed model and wired to four Ultrabright LEDs equipped with internal resistors. The circuit diagram can be seen in Figure 23.



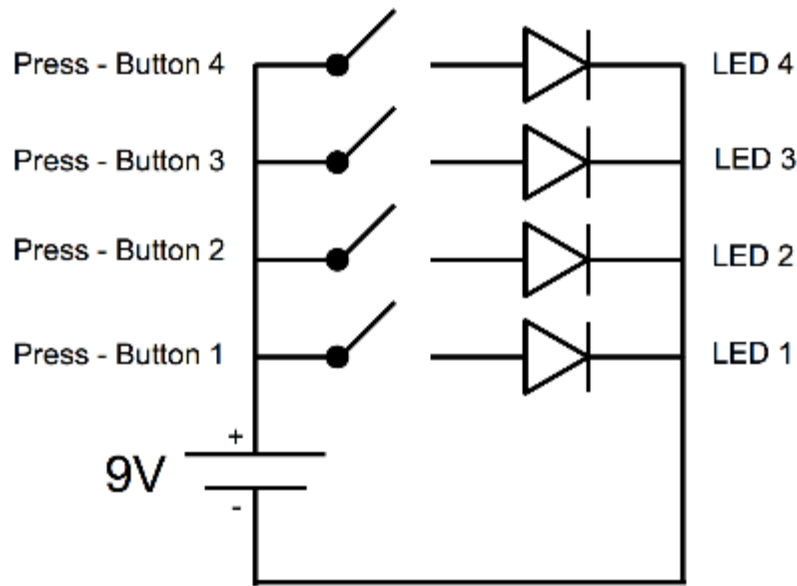
*Figure 22 - Zuni Mission with Buttons*



**TABLE 4: TABLE OF BUTTONS PRESSED TO THEIR CORRESPONDING ARCHITECTURAL ELEMENTS**

Button Pressed	Corresponding Architectural Element
	
	
	
	





Note : The LEDs are equipped internal resistors

Figure 23 - Circuit Diagram

**Touch Table:**

The physical learning outcome assigned to the touch table--*visitors will be able to identify the composition, uniqueness, and architectural purpose for each specific site's physical features outlined in the 3D model*-- describes the procedure and materials used in order to create the architectural elements displayed by the 3D printed model. This is because there will be only one touch table in the room and it will be best suited to give an explanation on elements that are common amongst all the six sites, while still able to display their differences as well (IDEUM, personal communication, September 6, 2018). Our sponsor's current touch table can be seen in Figure 24.



*Figure 24 - Touch Table belonging to the Jojola lab*

For the prototype exhibit, the touch table will depict information specifically regarding the Old Zuni Mission and the Isleta Head Start Building, listed below in table 5 and table 6. This information is from personal communication with Norman Cooyate, the former governor of Zuni; Tom Kennedy, the Zuni Tourism Director; and Wells Mahkee, a Zuni Tourism Board Member.

**TABLE 5: ZUNI MISSION PHYSICAL FEATURES AND INFORMATION**

<b>Physical Feature</b>	<b>Touch Table Information</b>	<b>Touch Table Optional Extra Information</b>
Adobe	Real adobe bricks make up the base wall. Over time this wall has been covered with stucco cement.	The adobe was covered with stucco cement mixed with gypsum. This was done in order to shield the adobe from the elements. Most stucco cement used to cover historical buildings is made with lime. Unfortunately, the gypsum mix is causing the building to fall apart prematurely.
Vigas	All vigas on the Old Zuni Mission are made of pine. The vigas in the front are original while the vigas visible from the outside were added in the most recent renovation in the 1970s. Additionally, the vigas are used to provide structural integrity.	The pine used to create the vigas was dragged by horses from over 25 miles away.
Latillas	The latillas on the Old Zuni Mission are made of red cedar. They provide additional structural integrity to the roof.	The red cedar used to create the latillas were dragged by horses from over 25 miles away at the request of the Mission’s friars.
Canales	The canales are made of pine. They direct excess water off the roof to protect against erosion.	The pine used to create the canales were dragged by horses from over 25 miles away at the request of the Mission’s friars.

**TABLE 6: ISLETA HEAD START BUILDING PHYSICAL FEATURES AND INFORMATION**

<b>Physical Feature</b>	<b>Touch Table Information</b>	<b>Touch Table Optional Extra Information</b>
Vigas	The vigas in the Isleta Head Start Building are made of steel and painted red. They serve no structural purpose and their existence is purely for aesthetic reasons.	Information not available
Adobe	The adobe-like material that makes up the Isleta Head Start Building is stucco cement. It is more structurally sound and lasts longer than real adobe while still looking similar.	Information not available

The touch table will expose the visitors to the fact that Puebloan architecture has many similar components, however, these components still have different cultural implications based on the Pueblo. For example, since most of the sites contain vigas of some sort, a ‘viga’ option will appear as each site’s tangible is placed on the touch table. Depending on the tangible, however, a cultural description of that viga will be available. For the Zuni tangible, ‘vigas’, ‘latillas’, ‘adobe’, and ‘canales’ options will appear. As each one is clicked, its description specific to the Zuni will be explained. This display is further outlined in the below images.

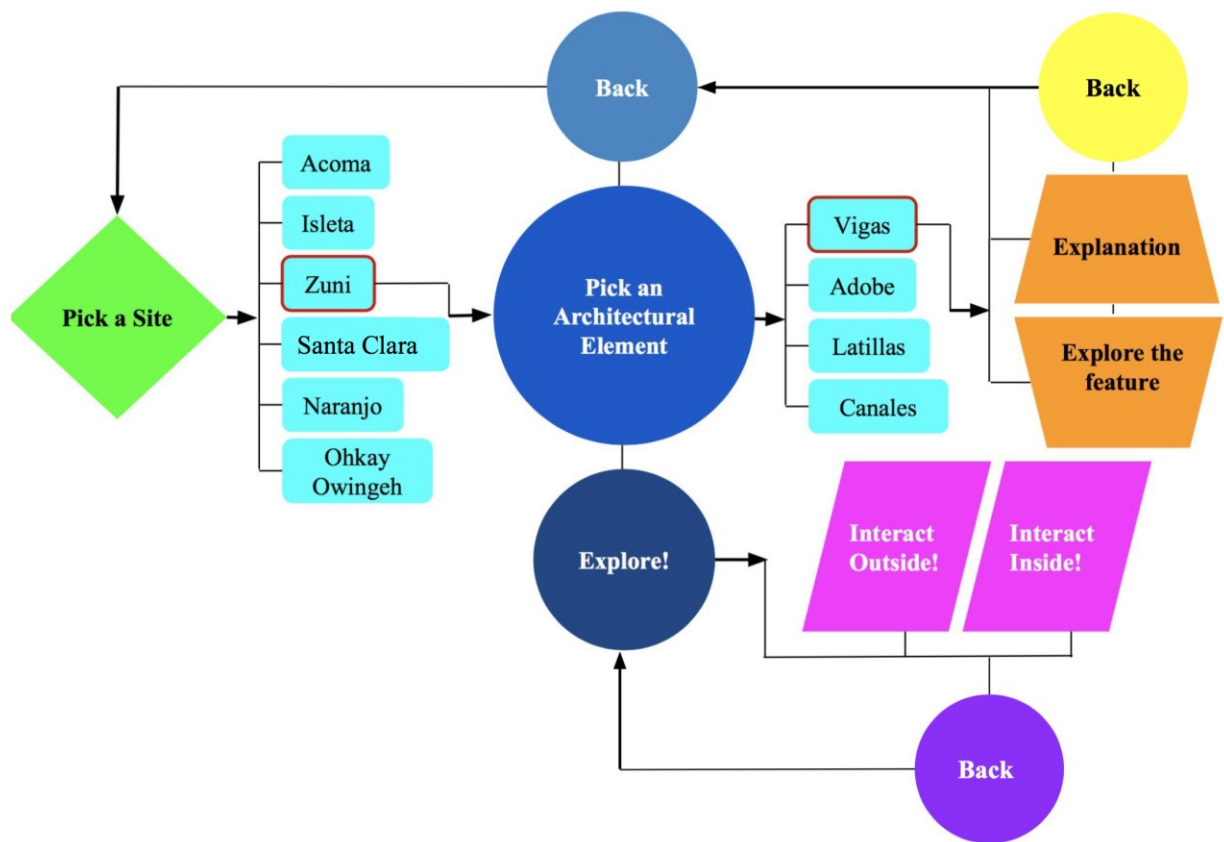


Figure 25 – Diagrammatic Representation of Touch Table Progression

The diagram in Figure 25 models our touch table framework and describes the path a visitor might take while at the table. The visitor will first pick a site by placing the tangible inside the dial on the table as seen in Figure 26. The white object in the center of the figure is a simplified footprint of the Old Zuni Mission tangible to be placed on the touch table.

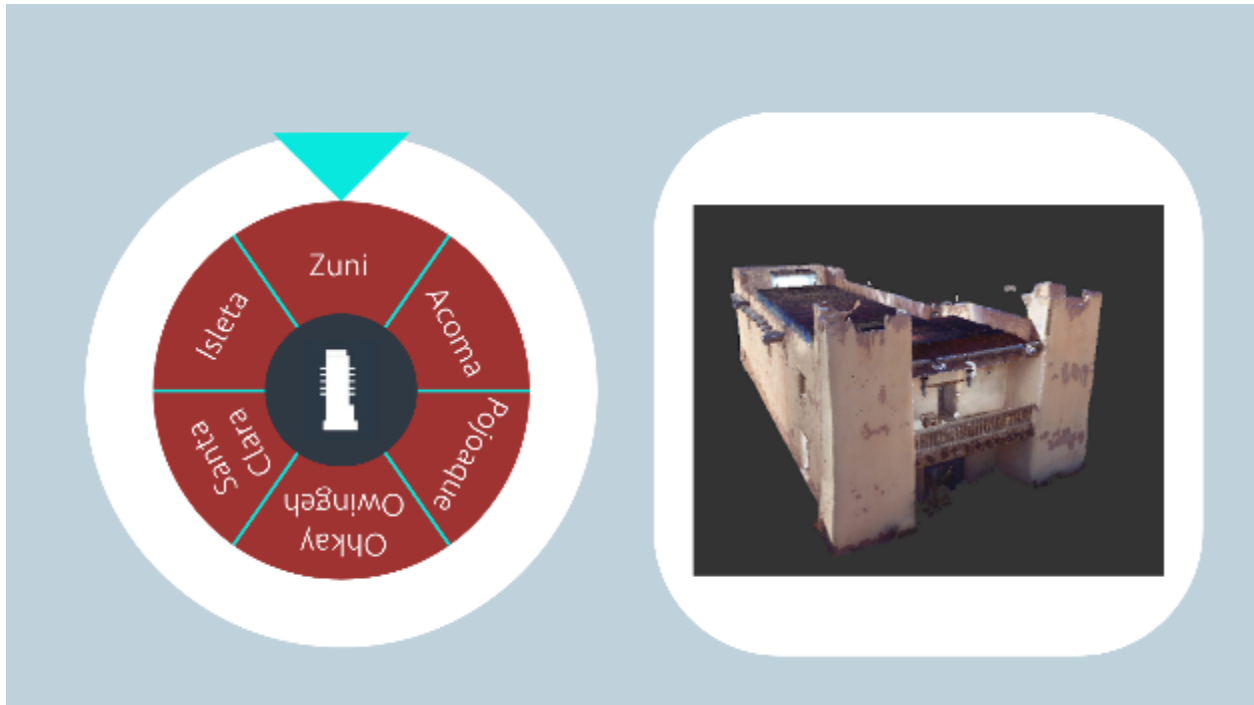


Figure 26 - Touch Table Site Dial with Tangible and Site to the Right

The dial will automatically rotate to “Zuni” and the image on the right will appear. The visitor will touch the site on the right. Following this command, the screen depicted in Figure 27 will appear, allowing visitors to move the dial until it lands on their desired architectural element.

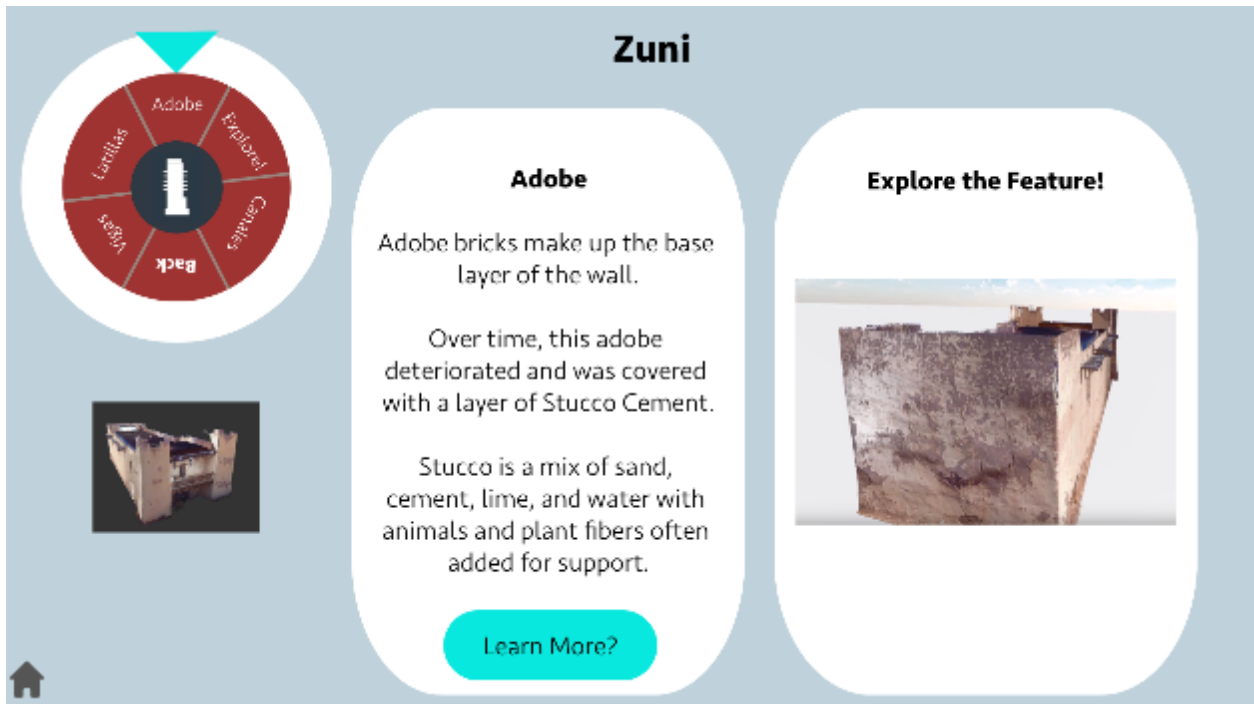


Figure 27 - Touch Table Physical Feature Dial with Information to the Right

The diagram above displays the “Adobe” being chosen. This then brings the visitor to a page where he or she can read about the element and explore the feature as well. This page provides a summary of the architectural element, but the user will have the opportunity to click for more information as seen in Figure 28.

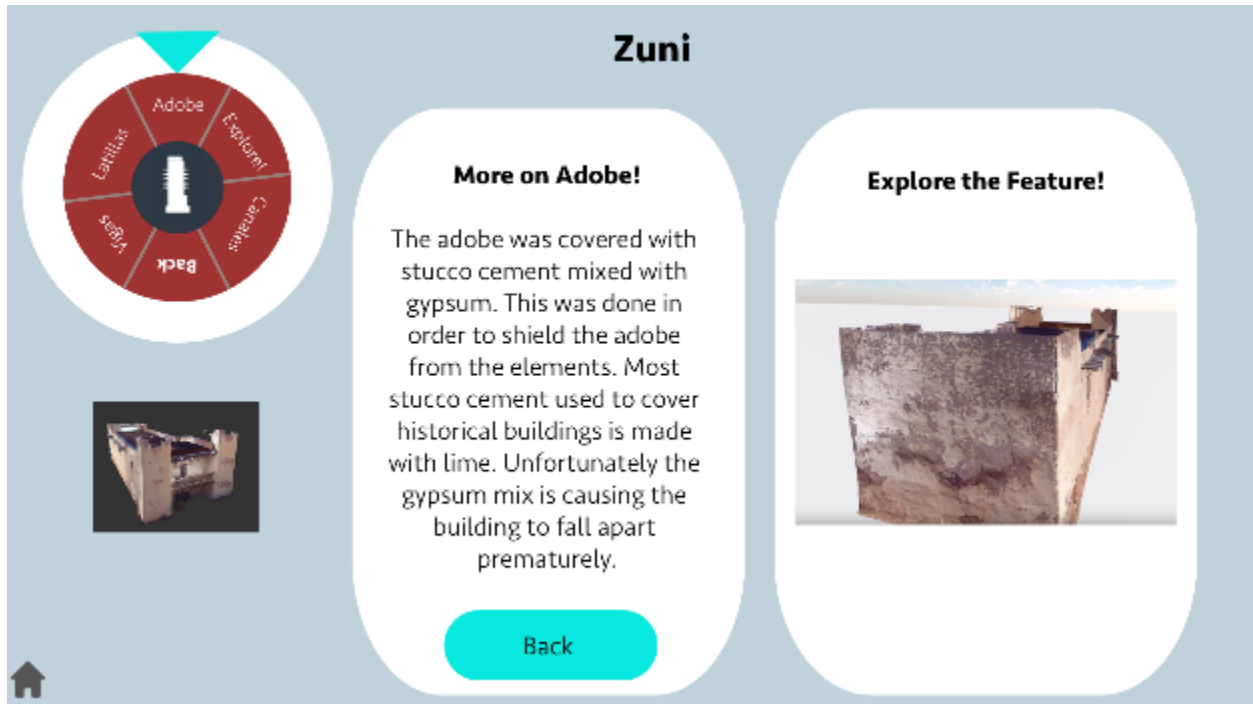


Figure 28 - Touch Table Learn More about Adobe Page

The explanation will discuss the materials used and the creation procedure for the architectural element. The option “Explore the Feature” allows the visitor to view the mesh model of the element. The visitor will also have the opportunity to pick the “Explore!” dial option, which opens up a new page where the visitor has the option to view a flythrough of the inside or outside of the building. Each slide contains the icon of a house in the bottom left corner. This icon will take the visitor back to the previous page. In the case of Figure 28, touching the back icon will take users back to the original Zuni Mission Adobe page, from there touching the house icon would take users back to the Zuni Mission site page. The complete touch table storyboard can be found in Appendix D.

**iPad:**

The learning outcome assigned to the iPad describes the specific contemporary influences--visitors will be able to recognize that and explain how contemporary Puebloan

*architecture has a base in traditional design but has changed as modernized worldviews become more prevalent--and community planning aspects--visitors will be able to recognize that and explain how Puebloan architecture often embodies community, spirituality, and reactive beliefs and values--of the corresponding site. A supporting brief history is also included. Two videos and one interactive timeline will be available for the user to choose from on the iPad. One video displays a brief history of the building, one describes the community and spiritual aspects of the building, and one is an interactive timeline displaying the contemporary influence on the buildings. The title slides for each video and timeline can be seen in Figure 29.*



*Figure 29 - iPad Title Slides*

The contemporary influence learning outcome shows the change in the building over time and the community and spirituality learning outcome as previously stated displays the cultural and spiritual meanings behind the architecture of the building. The contemporary influence video contains photos of the Old Zuni Mission from nine different years, with the first being a representative of the Mission pre-1849. The user will be able to click on the button corresponding to their desired year and watch the Mission change over time. A brief description of the state of the building at that time is also included. An example of the timeline can be seen in Figure 30.



The mission had been renovated once again in 1921 using similar architectural materials. This version did not have an attached covent.

This image depicts a deteriorated 1921 model right before the mission was again rebuilt in 1966.



Figure 30 - 1966 in the Contemporary Influence Timeline

The Community and Spirituality video displays information about the cultural and spiritual meanings behind the architecture of the building. This is done through the use of outside and inside fly-throughs that pause momentarily in four places where text is displayed to give the visitor the necessary information about the space that they are currently “in”. An example of the informational pause can be seen in Figure 31.

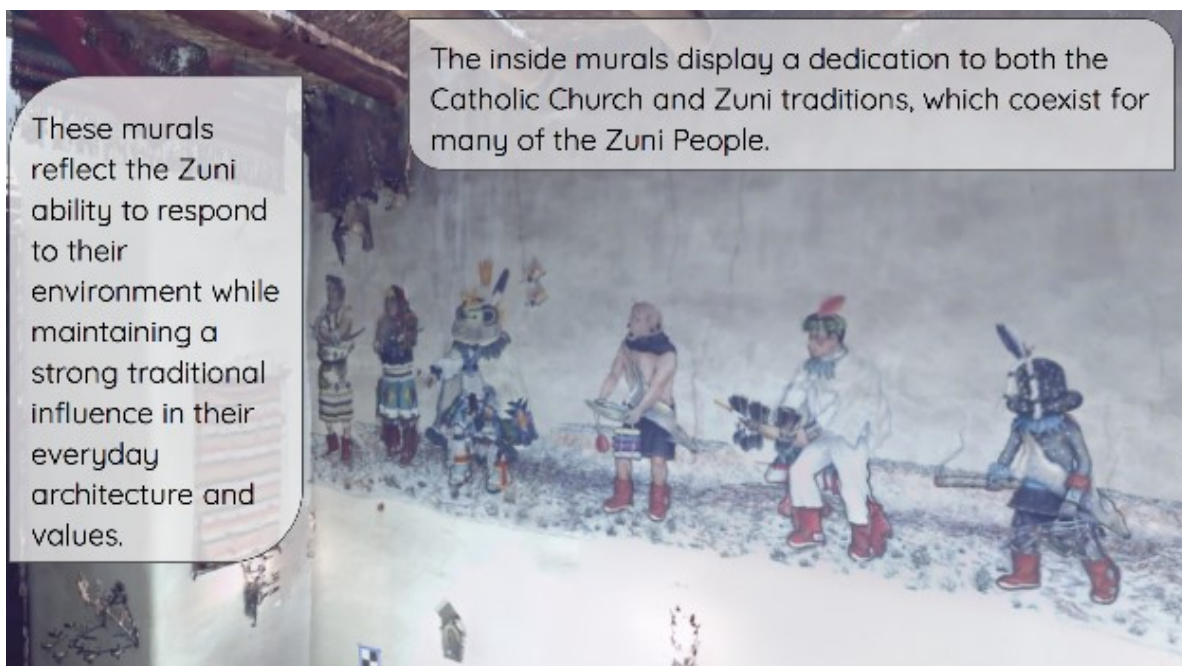
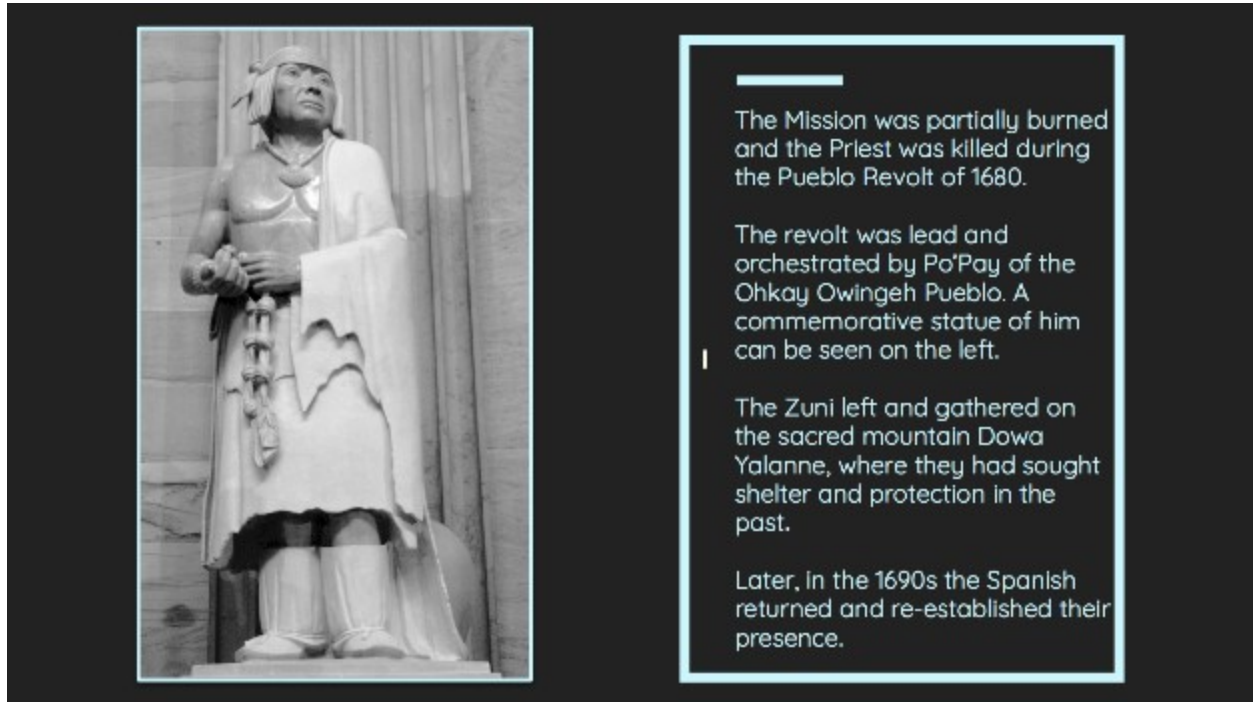


Figure 31 - Inside Mural in the Community and Spirituality Video

The iPad also displays a brief history of the site in order to give the viewer the necessary background. The small size of the iPad makes it possible for one to be dedicated to each of the six sites. An example of the Brief History video can be seen in Figure 32.





*Figure 32 - 1680s to 1690s in the Brief History Video*

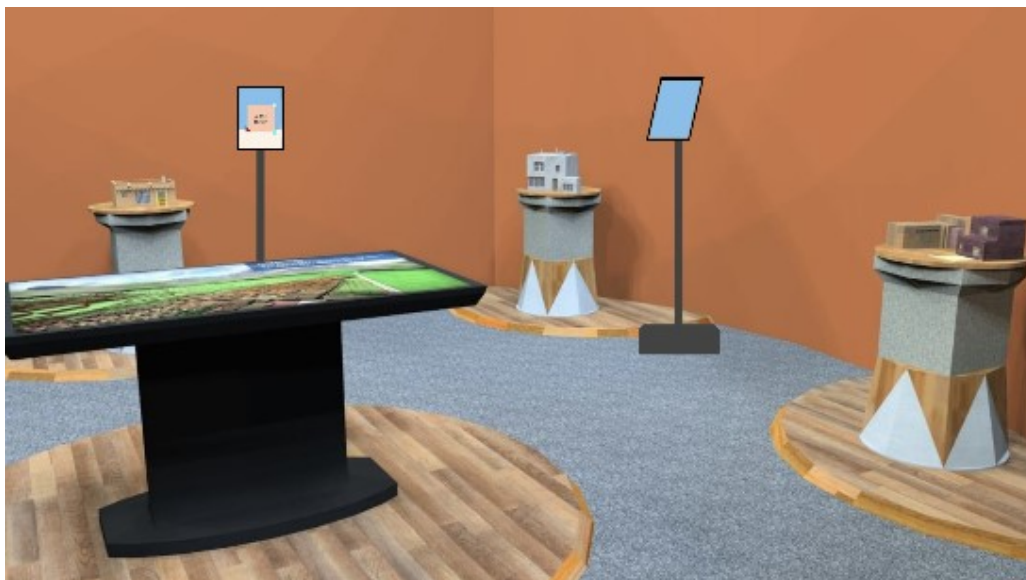
The full video and timeline storyboards can be seen in Appendix C.

### **The Flow of the Exhibit:**

The exhibit is designed so that a visitor can follow a single wall through the room and cover all of the information presented. The spread of information amongst the three media can be seen in Figure 33. The middle of the room is dedicated to the touch table while around the room, the site-specific 3D models can be found. The SketchUp model created by DeOliveira et al. (2017) can be seen in Figure 34 with our added iPads for each site. The figure below details each interactive component's contribution to the exhibit information.

<b>3D Printed Model</b> 	<b>IPad/Tablet</b> 	<b>Touch Table</b> 
<ul style="list-style-type: none"> <li>• Displays Architectural Elements with Interactive Push-Buttons</li> </ul>	<ul style="list-style-type: none"> <li>• Displays a Brief History Video on the Site</li> <li>• Displays a Community Planning Video With Corresponding Flythroughs</li> <li>• Displays an Interactive Contemporary Influence Timeline</li> </ul>	<ul style="list-style-type: none"> <li>• Displays Materials used and Creation of Architectural Elements Depicted by 3D Printed Model</li> <li>• Displays Inside and Outside Flythrough of Site</li> </ul>

*Figure 33 - Exhibit Distribution*



*Figure 34 - Exhibit Design*

Spreading the iPads, 3D models, and touch table throughout the exhibit will allow the visitors to enjoy multiple components and areas of the exhibit. This way, one location will not be crowded. Ideally, we designed the exhibit prototype so the visitors will first go to the 3D printed model and its corresponding iPad, and then they will go to the touch table to learn further about the physical components. This setup aims to disperse the visitors throughout the exhibit. Despite this, the exhibit is not required to be viewed in a specific order. Each aspect has its own interactivity and unique information. If one part is being used, there are plenty of other options

for the guests. A diagram describing the hypothetical route a visitor might take during their visit can be seen in Figure 35.

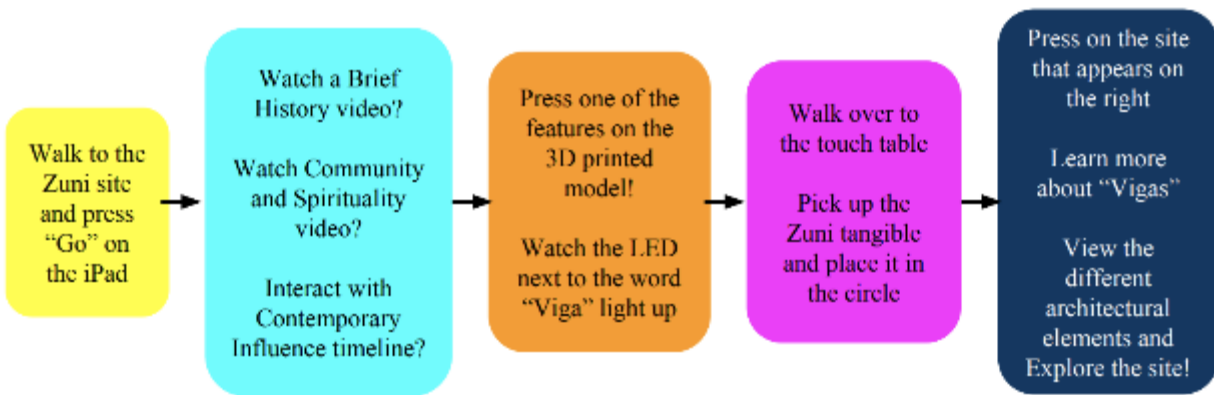


Figure 35 - Exhibit Flow

### 3.3.2 Conformed to Prototype Requirements and Constraints

Our prototype design is based on the requirements and constraints posed by our sponsor and the IPCC. Our prototype aims to attract more families and ensures that the exhibit can be a shared experience amongst the visitors.

As a result of conforming to the two levels of learning, found in section 2.3.2, we provided a 3D printed model which introduces visitors to the basic elements of contemporary Puebloan architecture. The iPad allows visitors to create a foundational knowledge of the site for themselves by watching the brief history video and gives them the opportunity to further their knowledge by, for example, watching the community and spirituality video. The touch table displays the fundamentals of each of the architectural elements, but allows users to get more information if they would like to further their knowledge base. Interactive and analog content are also dispersed amongst media to adhere to the preferences of various groups of visitors. According to the work of last year's IQP group, younger people enjoy analog displays more and older people enjoy digital displays more (DeOliveira et al., 2017).

Our exhibit conformed to the specification of providing a shared and communal experience for all users. The 3D printed model can be used by more than one person and can easily be spectated as well. The iPad will typically be used by a single user at a time, but many visitors will be able to watch the videos simultaneously. The touch table allows for multiple users and spectators depending on the size of the touch table.

### 3.4 Assessed exhibit effectiveness relative to learning outcomes and provided exhibit framework for further development

This section displays the outcomes of the guided survey with college students, in addition to documenting the process used in the Old Zuni Mission prototype. The latter also provides a concise framework for completing the rest of the IPCC exhibit.

#### 3.4.1 Guided Survey with College Students

A total of 11 WPI students participated in the guided survey after exploring the exhibit prototype on October 4, 2018. After the students went through the exhibit prototype, we provided them with a brief examination to evaluate their knowledge learned from the exhibit. Each question corresponded to one of our learning outcomes, so that we were informed on whether our digital and physical aspects of the exhibit were successful. A blank example of the test given to the college students can be found in Appendix F. The raw data obtained from the guided survey can be found in Appendix G. For each learning outcome, our test included either one question with multiple parts or multiple questions. This gave each learning outcome a variety of potential correct or incorrect answers. After each test, we recorded the percentage of answers each student got correct for the respective learning outcome and denoted this as the percent understanding. Once all tests were completed, we calculated the average percent understanding. As stated in section 2.4, we determined an average of 75% with each learning outcome constituted a successful exhibit. For our evaluation, we defined the percentage of average understanding as the percentage of correct answers per learning outcome for the average test subject. For the learning outcome regarding the identification of physical features, test subjects showed an average understanding of 84%. For the physical learning outcome regarding explanation of unique features, visitors showed an average understanding of 79%. For the influential learning outcome and the cultural learning outcome, the average understanding was 82%. From these results, we determined that our exhibit effectively presented all learning outcomes. These results are presented graphically in Figure 36 below.

### Percent of Correctly Answered Questions vs. Learning Outcomes:

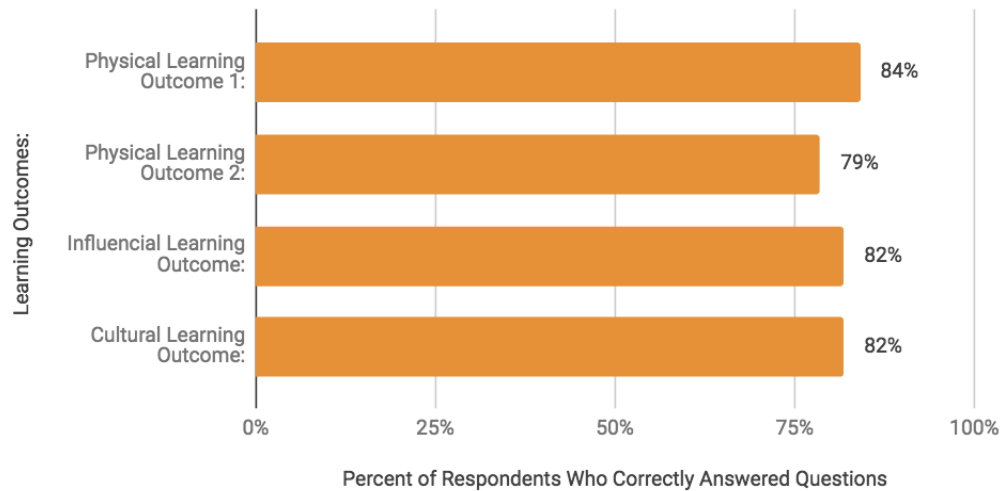


Figure 36 - Percent of Correctly Answered Questions Vs. Learning Outcomes Chart

From this we concluded that our exhibit accurately displayed and educated a group of college students on the intended learning outcomes.

#### 3.4.2: Documentation and Framework for Exhibition Completion

We created a document that describes the procedures used in the execution of this project. The document, located in Appendix A, contains 3 sections: the technical aspects of the project, the methods of interactivity and their purpose, and the site-related specifics of each individual building.

The first section, a technical manual, includes instructions on how processed LiDAR scan data was converted to 3D printable model, how LiDAR scan data was converted to maneuverable digital mesh model, how digital model was used on a touch table, and how a LiDAR flythrough was created and recorded. In addition to these instructional sections it includes a list of all necessary programs used in processing point-cloud information and the hardware requirements needed to run them. The subsections of the manual are organized into clearly listed and numbered directions on how to complete each part. These instructions were designed to be repeatable even by people unfamiliar with the technical aspects involved in the completion of the prototype.

The second section depicts the learning outcomes for the overall site. The information in the template was broken up by medium and describes the educational purpose of that method of

interactivity. While it does not include the cost and hardware requirements for each medium, that information can be found in Appendix E.

The last section contains all site-specific learning outcome applications. This section was organized much the same way as the template in the previous section, splitting up learning outcome applications based on the medium that conveys them. Because the Old Zuni Mission was the only exhibit included in our prototype it has a complete set of learning outcome applications based on each of the interactive aspects of the exhibit. In addition, the Isleta Head Start building was partially completed due to information we gained through a tour while visiting the site.

## 4.0 Deliverables and Recommendations:

In this chapter, we detail the materials we provided our sponsor with throughout this project. In addition, we discuss the alternate applications of each deliverable to the final iArchitecture exhibit.

### 4.1 Exhibit Continuation Plan:

In this section, we explain the recommended use of our Technical How-to-Manual for managing LiDAR and 3D printing data of the remaining five sites: The Isleta Head Start Building, the Haak'u Museum, the Tessie Naranjo Residence, the Poeh Center, and the Owe'neh Bupingeh Preservation Project. Furthermore, we outline our recommended procedure for determining site-specific learning outcome applications.

#### 4.1.1: Technical How-to-Manual.

Our project completed the LiDAR and 3D model prototype of the Old Zuni Mission. For the final IPCC exhibit, however, iD+Pi still must complete this process for the remaining five architectural sites. To aid in this process, we created a detailed step-by-step instruction manual that walks through our procedure in FARO Scene, Autodesk ReCap 360, GeoMagic X Design, Autodesk 3DS Max, and SolidWorks. This manual is viewable in Appendix A. **We recommend that iD+Pi reviews the processes we describe in our manual prior to downloading and using these programs.** Doing this will allow for more accurate planning and reduce wasted time in the many technical processes involved with LiDAR data.

For the creation of mesh models, our team found that creating and portraying isolated mesh features is both a timely and costly endeavor to continue for each remaining site. As seen in Appendix E, the programs that are needed to construct mesh models alone would cost iD+Pi an additional \$21,455 on top of the \$16,751 in annual licenses required just to fully process LiDAR point-cloud data. **We recommend that iD+Pi avoids mesh-model creation due to these costs and instead considers buying or upgrading a powerful computer capable of viewing LiDAR data in real time, eliminating the need of optimized mesh models.** Based on the program system requirements listed within Appendix A, we define a powerful computer having (or being equivalent to) an operating system of 64-bit Windows 7, a 2 GHz minimum 8-core Intel Core i7 CPU, a non-integrated 2 GB NVIDIA Quadro GPU, 8 GBs of RAM memory, and a SSD with more than 256GB of storage.



As of the completion of this project on October 12, 2018, iD+Pi and NTU were in the process of finalizing complete LiDAR scans of the Isleta Head Start Building and the Ohkay Owingeh Owe'neh Bupingeh Preservation Project. Therefore, **we recommend that iD+Pi waits to begin the model design process until the LiDAR scan data has been fully collected.** We recommend this because the LiDAR scans of the Old Zuni Mission that we worked with were missing roof-scan data. This restricted us by limiting our access to roof measurements.

#### **4.1.2: Continuing Learning Outcome Illustrations.**

The learning outcome illustrations refer to how each learning outcome manifests itself throughout the architectural sites. A major deliverable of this project was a written document detailing the general learning outcomes for the iArchitecture exhibit, as found in Appendix B. Later, we explained how these outcomes are demonstrated by the Old Zuni Mission and the Isleta Head Start Building. The purpose of this document is to organize the reasoning behind the exhibit, as well as how the exhibit's purpose can be demonstrated through each site both independently and collectively. For the remaining four sites we included a list of questions to which the answers will help generate learning outcome applications.

As iD+Pi continues to build the exhibit, we **first recommend that they utilize the pre-existing Isleta Head Start learning outcome illustrations detailed in Section 3.1.1.** These illustrations depict various cultural and physical aspects of the building that would successfully contribute to the iArchitecture exhibit. They can serve as a focus while constructing the various digital and physical models needed in the exhibit. **Additionally, we recommend that iD+Pi use the provided questions detailed in Section 3.1.1 when establishing the learning outcome illustrations for the remaining four sites.** The questions were established in collaboration with the AOS Architects and members of the Zuni Pueblo, making the questions culturally accurate. By using these questions as a formulaic method of establishing the relationship between sites and learning outcomes, the exhibit will remain centered on reiterating common themes within Puebloan architecture. The framework questions served as our basis for the Old Zuni Mission and Isleta Head Start Building, and continuing this process will ensure a focused and clear final exhibit.

Alternatively, iD+Pi may wish to add further types of information to the exhibit continuation manuals, such as where each building is associated with its representation of more traditional or contemporary Puebloan architecture. The exhibit continuation manual refers to the

learning outcome and technical how-to manuals. More information will not only increase the knowledge gained by the visitors, but it will also increase the potential discrepancy between site models. **Therefore, we recommend that iD+Pi use the exhibit continuation manual to record all additional informational material added to each site.** Additional information can include additional learning outcomes, additional technical programs, or additional learning outcome illustrations. Using this manual will limit the difference in information presented by each site, ultimately securing the cohesion of the exhibit. Additionally, using the manual to record added information will also provide a more effective and efficient way to store the informational portions of the exhibit.

## 4.2 Partial Exhibit Prototype:

Another major deliverable of this project was our exhibit prototype featuring the Old Zuni Mission. This prototype is a three-part exhibit with an interactive 3D printed model presenting the physical architectural elements of the site, an iPad displaying the site's contemporary influence and community and spirituality, as well as a touch table showcasing the materials used and the creation of each site's architectural elements. We have also provided our ideal flow for the rest of the exhibit. This involves each site being given their own 3D printed site model and iPad displaying the specifics for that site. In addition, this involves the touch table being at or near the center of the room and providing information that is common among all the sites.

### 4.2.1: 3D Printed Model.

For the continuation and completion of the exhibit, we have split up our recommendations among each of the three-exhibit media. **For the 3D printed model, we recommend that each building is modeled and printed in small individual parts for later assembly.** Modeling the building in individual parts will make adding separate color and texture easier. Printing in separate parts will decrease the amount of supports necessary and will make fitting multiple pieces on a build plate easier. Additionally, it is best to print the models as a filled piece, rather than with a visible inside. This lowers the printing cost as less support material is necessary and the LiDAR digital model provides a more detailed depiction of the inside features. While the pieces should all be modelled separately, similar pieces should be printed together. In this project, we printed fifteen total files divided into six total printing cycles.

Printing like-pieces together reduces the necessary print time for the entire model. While this is not possible for the large portions of the print, it works well for the small features such as windows, vigas, and doors.

In the creation of our model, we varied the printing specifications between 10 and 20 percent infill (internal fill density) and 0.2mm vs 0.15mm layer height. **Using 0.15mm layer height and 20% infill creates a better quality model, but uses slightly more material. We recommend that iD+Pi uses these setting during the creation of their future models.** Lower layer creates a better-quality model as more layers are needed to do the print. As a result, any details or curves are printed in more parts. More infill creates a higher quality model as the internal strength of the model increases with the percentage that is supported and filled. The difference in quality is significant while the increased print time and material usage is minimal. Alternatively, iD+Pi can further reduce the layer height and increase the infill to get a higher quality model. However, any discrepancies in the print, such as small errors in the print layers, with the recommended specifications can easily be covered when the model is painted.

During our project, we only had access to LiDAR scans of the Old Zuni Mission without the roof. As a result, we did not have access to proper roof dimensions during model creation. Since this exhibit intends to expose cultural accuracy, it is important that all measurements are available when creating final models.

When adding an interactive component to the model, **we recommend that tactile push-buttons ranging between 3mm x 4mm x 2mm and 6mm x 6mm x 3.1mm be used and placed in the model.** This size range will do well in all six interactive models. These make fitting the buttons into the model much easier and provide a range of possibilities for how they can be placed. When painting, we found that mixing sand with the paint works very well when attempting to add an adobe texture to the model. For safety and aesthetic reasons, **we recommend that ultra-bright pre-wired LEDs be purchased and that dome shaped opaque covers be printed for them.** The opaque covers will shield the visitor from the intense luminosity of the ultra-bright LEDs. It will also prevent the LEDs from accidentally being ripped off by visitors and potentially causing a risk of electrocution.

#### **4.2.2: Storyboards**

The storyboards included in our deliverables for the prototype exhibit are split up between the iPad and the touch table. There are three iPad storyboards, a Brief History video, a

Community and Spirituality video, and a Contemporary Influence timeline. The touch table has a single storyboard that covers the creation and materials used in the architectural elements presented to the visitor by the 3D printed model. We have divided up our recommendations between each of these storyboards.

### **iPad Storyboards:**

For the Zuni Brief History Video, we recommend that former governor of the Zuni Pueblo, Norman Coeoyate, completes a voice over of the written material. The former governor is a faculty member at UNM and will both be easily accessible due to his location and a will provide the voice of a respected figure. **We further recommend that a voice over of the written material be extended to all six sites, each incorporating collaboration with a representative from the respective site.** A voice over will give viewers a choice between reading or listening to the material. The written material for the rest of the sites will need to be written by an authority on each Pueblo and their respective site. This will decrease the possibility of error in the portrayal of each site's history.

The Community and Spirituality video will similarly require a voice over. This will provide the viewer with the option to read the material or to listen to it. **It is recommended that the representative tasked with writing the Brief History for their respective Pueblo's site also be tasked with writing or reviewing the material for the Community and Spirituality videos.** This will provide the viewer with authentic information spoken by an informed representative. We recommend that when including the flythroughs for the video that a single flythrough be rendered and then split up and paused between each informational stopping point. This will ensure a smooth and quality final video.

**We recommend, for the Contemporary Influence timeline, that pictures from similar angles of the Mission and of future sites be procured for each year on the timeline.** This will give the user a more comprehensive understanding of the building's change over time. We would also like to recommend that more years are added to the timeline. More years will display a more thorough reflection of the building's change over time.

### **Touch Table Storyboard:**

**For the touch table storyboards we first recommend that the information for each site be completed. Afterwards, we recommend that a high-powered computer is used to run**

**the software described above in order to produce an interactive rendering of the model.**

This will allow the user to spin and turn the model in the “Explore the Feature!” section on the touch table. This will also allow a visitor to maneuver through the different flythroughs.

Currently our touch table provides an image of the model and a video of the inside and outside flythrough. As a note, we would like to recommend that all possible touch table options are investigated, even though we expect that an IDEUM touch table might be the best alternative for the final exhibit. This is recommended because IDEUM is a local company that will be able to program the table to recognize the tangibles for each site. They will further be able to meet any size requirement for the table. Working with a local business will likely lower shipping costs of the table and if there are any issues with the table, they would be close enough to send a representative.

#### **4.2.2: The Exhibit Flow**

**We recommend that our plan described above and in section 3.3.1 for the flow and layout of the exhibit be used.** This will allow visitors to spread out amongst the different interactive media and will encourage movement throughout the room. **Furthermore, we recommend that as the exhibit is being designed, the varying levels contemporary influence by each site be kept in mind.** For this, we recommend that the Zuni Mission be the last site the visitor sees as he or she walks around the room. As the possible renovations on the Zuni Mission are still being decided, this will give the visitors a chance to view how other Pueblos have reacted to contemporary influence and will allow them to ponder how the Mission might be renovated.

#### **4.3 Focus Group Evaluation Guide:**

We have two purposes for recommending focus groups be conducted in the future. First, it would be useful gain insight into what visitors learned from the interactive exhibit and if they match our learning goals. Second, we want to ensure that the important cultural aspects of Puebloan architecture are portrayed in an acceptable way for their respective tribe. For this reason, we determined that two separate categories of focus groups should be organized, one with young adult visitors to the IPCC, and the other with Puebloan site liaisons. We are, however, limited by the time we are working in Santa Fe and by the amount of LiDAR data we have available. As a result, we suggest that our sponsor conducts these focus groups for the final

exhibit. We will, however, present a set of questions to be asked during each focus group for our sponsor to follow as a deliverable.

#### **4.3.1: Focus Group with IPCC Visitors**

**We recommend that an initial focus group be done with IPCC visitors in order to obtain feedback on the effectiveness of allowing visitors meet our learning goals and to get their opinion on how the information was transmitted.** By determining how well the exhibit educates the audience and on the effectiveness of the medium, iD+Pi will be able to evaluate the effectiveness of the exhibit and incorporate changes into their final design.

In this study we suggest iD+Pi ask the recommended questions we included as a deliverable in Appendix I. We suggest that they leave each question relatively open for discussion among the participants, and in doing so, the subjects' responses and thoughts on the exhibit will be natural. Furthermore, the interviewer should promote a more dynamic discussion, letting the group decide how to expand on it, and the interviewer merely guiding the questions that they want answered. While the interviewer's participation in the conversation should be limited to a guiding role, they should take notes on the outcomes of the discussion to later determine the effectiveness of their exhibit and incorporate feedback.

#### **4.3.2: Focus Group with Pueblo Site Liaisons**

The purpose of proposing this focus group is that we want to ensure that the final exhibit represents the unique architectural styles and cultural influences of the Acoma, Ohkay Owingeh, Isleta, Zuni, Pojoaque, and Santa Clara Pueblos, in a way that members of these tribes are comfortable with. Therefore, **we recommend this focus group should consist of six representatives, each well versed in their own Pueblo's respective cultures, so that iD+Pi can ensure the exhibit's collective cultural accuracy.**

During this study, **we recommend five guiding questions, found in Appendix H, to determine which aspects of Puebloan architecture, cultural and physical, are important to include in the exhibit and if they were portrayed correctly.** Each question should then be open for discussion among the participants. While participation of the researcher in the conversation would be limited, they should take notes on the outcomes of the discussion to later determine the effectiveness of the exhibit. Afterwards, feedback should be incorporated into the exhibit design in order to address their suggestions.

In addition to recommending a focus group with Pueblo site representatives, **we also recommend allowing the Puebloan tribes involved in the project to take the portion of the exhibit that relates to their Pueblo and be allowed to put it on display within their Pueblo, in order to get community feedback.** This feedback would be collected through a simple comment box after they view a piece of the exhibit. It would be more beneficial to collect community response this way because the purpose of this exhibition would not be to answer a specific question, but to get the local people's impressions of the exhibit. If a large portion of the local communities respond in opposition to the creation and representation of the exhibit, then iD+Pi would have to re-evaluate the specific content of their project and speak with community leaders about how to proceed. For the Zuni Pueblo, the head of tourism, Tom Kennedy, has already expressed enthusiasm for putting the Zuni exhibit portion on display in the tourism office to promote interest in preserving the Zuni mission and allow a generation that has never seen the inside of the church to view the murals (Zuni Tourist Director, Personal Communication, September 21, 2018).

#### **4.3.3: Exhibit Recommendations from Guided Survey:**

Following our guided survey, we took into consideration the student feedback and arrived at a few suggestions that would better iD+Pi's final exhibit.

**We recommend the respective location of the buttons and lights on the 3D printed model be switched such that the lights are placed within the 3D model itself and the buttons are on the feature labels.** Surveyed visitors were initially confused on both the placement and intended use of the buttons placed within the 3D model. If the site buttons remain within the 3D model, they should have stronger visual button indicators and a more durable construction to endure incorrect button use.

**We recommend that the image of the architectural site on the touch table be identified as the touch point to access that respective sites physical feature menu.** The initial touch table navigation was unclear for surveyed visitors as it lacked a clear visual indication for continuing to site information once a site was selected.

**We recommend that all features on the physical model be identified and include a brief explanation of their reasoning, even if they do not include an interactive button.** Each building has unique features and even if they do not fall into the category of common Puebloan architectural components it is important that they be identified in case visitors want to learn more

about a specific site. For example, the Old Zuni mission contains a priest passageway that was not identified due to it only being present in this building. Even if it is not identified by a button, it would make the exhibit more informative to have brief descriptions of individualistic components such as the passageway.

**We recommend that each site tangible be encased in a strong clear container.** We observed that visitors dropped and broke pieces of the tangle on multiple occasions. Encasing the tangible will prevent any major damage from impacts and drops in the final exhibit.

The addition of these suggestions would increase clarity of the presented information as well as better the overall exhibit appeal.



## **5.0 Conclusion:**

We created a functioning interactive partial prototype for future development and use within the iArchitecture exhibit. The prototype includes a 3D printed model, an app containing the touch table storyboard, an app containing the iPad storyboard, and an exhibit continuation manual. We recommended to iD+Pi that they continue the exhibit creation through the use of the framework we developed to ensure cultural validity and visitor usability. We learned the capabilities and applications of LiDAR technology from digital representations to physical 3D printed fabrication. Additionally, we incorporated various methods of interactivity to best ensure cultural accuracy through design.

The purpose of this project was to aid iD+Pi in creating an exhibit prototype for their iArchitectre exhibit. Our intentions were to increase representation and enhance the appreciation of Pueblo contributions to contemporary architecture for modern architectural professionals, contemporary society, and Puebloan young adults. We hope that our final deliverables will be of significant contribution to iD+Pi's overall goal, and will act as a catalyst for renewing societal perceptions on indigenous cultural and architectural influence.

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## Appendix A: Technical How-to Manual:

### Program Instructions:

#### **How to Process, Clean, and Export LiDAR Scan Data:**

1. Import individual LiDAR scan point-clouds into FARO Scene to unify the point-clouds.  
*This process a time/system-intensive step.*
2. Export Scans from FARO Scene as a single .pts file.
3. Import .pts file into Autodesk ReCap 360 and Index. Save as ReCap project file once completed. *This process a time/system-intensive step.*
4. In ReCap 360, Use the window or fence select tool to select the main site points. This is best done in orthographic view, which can be selected in the Display Settings “Toggle UI Elements”
5. Go to the “Project Navigator” by pressing “Q” and click the “add a new region” button. Once named, Lock and hide the region using the lock and eye symbols.
6. Zoom out and select the remaining outlier point data and press Delete. *This process a time/system-intensive step.*
7. Unlock and unhide the site region. Using the fence select tool, begin deleting smaller point noise created by windows, power lines, or people.
8. Once cleaned, save the file as a new project. Then, Export the file as a .e57
9. A video guide of these steps can be found here: <https://www.youtube.com/watch?v=jr77-xs5GKA>

#### **Processed LiDAR Scan Data to 3D printable model:**

10. Still in ReCap 360, select the distance measurement tool. Begin measuring and recording key site dimensions for features, beginning with floor plan, height, and ending with windows, doors, and viga locations.
11. Visually break the scan data into pieces that can be easily 3D printed (Printers can handle overhanging objects with supports however this uses a lot of unnecessary time and filament)
  - a. For Example: The Old Zuni Mission was broken down into:
    - i. The Back Side (Ending with the vigas)
    - ii. The Front Side
    - iii. The Vigas Themselves (Outdoor/overhanging portion)
    - iv. The Canales
    - v. The Large Viga and Latilla Roof Platform
    - vi. The Small Viga and Latill Roof Platform
    - vii. The Windows
    - viii. The Wood Above the Windows
    - ix. The Doors
    - x. The Deck

- xi. The Railing
  - b. Modelling these parts individually will allow for easier attention to detail, the ability to alter colors / textures that may vary from piece to piece, and easier 3D printability.
12. Open Solidworks and begin modeling using the exact measurements taken in ReCap 360, starting from the larger features and ending with smaller details.
- a. Starting with the larger features provides a better outline of the model. This, in turn, results in better looking proportions when the model is complete
13. Once the Solidworks model is complete, download the necessary 3D printing software depending on the printer being used.
- a. Typically, each printer has a different software as they all have different filament capabilities and printing volumes
14. Save each 3D model created in SolidWorks as a .stl file. This is done by opening the model then clicking file, save as. From here choose the drop down arrow in the file type bar and choose .stl. Before clicking save, click the “options” button on the save as screen to decide the level of detail you want in the stl file. For the Old Zuni Mission, all stl files were saved as “fine”.
- a. Note: Nearly all 3D printing softwares can be used to save models as stl files in a similar fashion. SolidWorks was used due to its availability and user friendliness
15. Make a list of the number of each model you will need to print.
- a. For Example: The Old Zuni Mission 3D printed model requires
    - i. 1 Back Side
    - ii. 1 Front Side
    - iii. 26 Vigas
    - iv. 2 Canales
    - v. 1 Large Viga and Latilla Roof Platform
    - vi. 1 Small Viga and Latill Roof Platform
    - vii. 3 Windows
    - viii. 8 Wood Above the Windows
    - ix. 2 Doors
    - x. 1 Deck
    - xi. 1 Railing
16. Decide which of these models can be printed in the same print. Since most print beds are relatively large, they can process multiples of the smaller objects.
- a. For Example: The Old Zuni Mission will be done using 7 prints:
    - i. The Back Side
    - ii. The Front Side
    - iii. All the Vigas
    - iv. The Canales, The Window Wood
    - v. The Large Viga Roof, The Small Viga Roof, The Deck, The Railing



- vi. The Windows and Doors
  - vii. A very small scale, full model
17. For each of these prints, upload the .stl files to the 3D printer software.
    - a. Most softwares are smart enough to not pile the objects on top of each other, but sometimes they may have to be moved to allow for enough space
    - b. When printing a model in multiple pieces, make sure all pieces are the same scale, this will allow for correct assembly upon completion
    - c. Most printing softwares have a single toolbar that controls any rotation, scaling, or moving that needs to be done.
  18. Once the models are uploaded and positioned for each print, alter the print settings. The nozzle size is commonly set to 0.4 and the infill is usually set to 10-20%. Lowering and raising these respectively will increase print time as well as model detail. However, this setup is good for most applications.
  19. Press the button within the program that “slices” the print, this will give you an estimated print time as well as generate the .gcode file for the print which is plugged into the printer.
  20. Save the .gcode file once it is generated
  21. Save the gcode file onto a flash drive, SD card, etc. depending on the printer requirements.
  22. Upload to the printer and make sure all settings match the material being used.
  23. Push go

### **How to Convert from LiDAR Scan Data to a Maneuverable Digital Mesh Model**

1. Complete steps 1-7 from “How to Process, Clean, and Export LiDAR Scan Data”
2. We recommend doing the following steps with the LiDAR data for only one key feature at a time (i.e. one roof section) to reduce program crashing and wait times. To do this, open Autodesk ReCap 360 again, save as a new file, and delete all points besides the feature you want to convert to mesh using a similar process described earlier. Once isolated to just one feature, export again as .e57.
3. Import that .e57 file type from Autodesk ReCap 360 into GeoMagic X Design.
4. Select “Point Cloud” in the upper ribbon. With the LiDAR object selected, then choose the “Sampling” option. For the sampling options, use: “Uniform Distance”, Average Distance as 0.01 mm, Auto Sampling Ratio, and check Preserve Boundary. Press the Check to begin the process
5. Next, choose the “Construct Mesh (Poly-Vertices)” option within the Point Cloud ribbon. This will reconstruct and connect the LiDAR points into polygonal surfaces. The settings we recommend are: Mesh Construction, Tight Geometric Capture Accuracy, 0.065 mm Scanner accuracy, and check Remove Original Data and Reduce Noise. Press the Check to begin the process, this may take a long time.

6. For a video guide related to the steps above, refer here:  
<https://www.youtube.com/watch?v=5S3oleLWjrU>
7. Once completed, export the project as either .OBJ or .STL (binary).
8. At this stage, the mesh may still be too large in size for real-time manipulation (i.e. 10+ million vertices). To optimize the model further, we recommend using Autodesk 3DS Max. (The following steps can alternatively be done within GeoMagic and Blender with similar instructions)
9. In Autodesk 3DS Max, choose “Import” > “Import” to import the .OBJ/.STL. This may take a long time.
10. Once imported, click the main viewpoint and press “7” for model statistics. Write down the current vertex count.
11. Select navigate to the Modifiers tab and with the mesh selected, choose “ProOptimizer” and click the “Calculate” button within the “Optimization Level” on the side bar.
12. We recommend optimizing meshes below 2-3 million vertices. Change the Vertex % so that the After Points are low enough. (i.e. a 10 million vertex mesh would have a Vertex % of 25). This intensive process will take a long time.
13. Once completed, save. You may need to scale and translate the mesh depending on your application. Export the mesh now as either .OBJ, .STL (binary), or .FBX to import to a 3D viewer of your choice.

### **How to Create and Record LiDAR Flythrough:**

1. Complete steps 1-7 from “How to Process, Clean, and Export LiDAR Scan Data”
2. With Faro Scene open, go to the FARO 3D App Center website and navigate to the “SCENE Plug-In Apps” tab: <https://3d-apps.faro-europe.com/product-category/scene-plug-in-apps/>
3. Search “Video” to find the free video plug-in, or use this link: <https://3d-apps.faro-europe.com/product/video/> . This free tool records flythroughs in Scene with a watermark in the video. “Video Pro” is a watermark-free alternative that has the exact same features. A 7-day Trial of the pro version exists. We recommend doing the following steps with the free version first as it may be time consuming.
4. Download the Video plug-in from the website and go back to Scene. A free Faro account may be required.
5. Click the “Apps” button in the upper right corner, to the left of the Settings gear. Then click “Apps” again in the top left corner. In the new window, click “Install” and select the downloaded plug-in file. It will be successfully installed once the plug-in icon is on the top ribbon.
6. Open a Scene project, load the 3D view, and proceed to the “Explore” tab at the top.
7. You are now ready to create the fly path for your video. Maneuver the view to the desired starting point of your flythrough. In the top ribbon, click “Viewpoints” and then “Create”. It is recommended to name your points with numbers (i.e. “View1”)

8. Proceed to the location of the segment of the flythrough. Viewpoints act as points in a spline line, continue to create your path with this in mind and evenly spacing out your Viewpoints.
9. Once you reach the desired ending view, go back to the “Apps” button and now click on the “Video” icon and “create a new camera path”.
10. Add your SCENE Viewpoint do the Camera Path Viewpoints in order. Consider the path shape you would like; the Viewpoint-inclusive spline matches the exact locations of your Viewpoints while the Viewpoint-exclusive spline prioritizes path smoothness. Click “Preview Path” to sample your path in real time.
11. Once satisfied, save the Camera Path (and the project file). To render, click “Next>>”
12. Now set the Video graphics, speed, and frame-rate. We recommend the following settings for HD flythroughs: H.264, 16:9 1920x1080, 30 fps, Very High bitrate. For more information on render settings, view the Scene Video Plug-in user manual: [https://3d-apps.faro-europe.com/wp-content/uploads/sites/9/2017/06/e1315\\_video\\_1-1\\_manual\\_en.pdf](https://3d-apps.faro-europe.com/wp-content/uploads/sites/9/2017/06/e1315_video_1-1_manual_en.pdf)
13. Click “Start” to render your flythrough video. With the settings recommended above, it is estimated to take 4 hours to render 1 minute of footage.

## Program Requirements:

### **FARO Scene:**

#### Recommended:

- Processor: Quad-core X64, Intel Core i7/Xeon, 8 physical cores
- Graphics Card: Dedicated graphics card, OpenGL 4.1 or higher, at least 4 GB Memory, For Stereo Rendering: NVIDIA Quadro; For VR Rendering: NVIDIA 1080GTX or similar, SteamVR must be installed, Supported VR Headsets: Windows Mixed Reality, Oculus Rift with Touch Controllers, HTC Vive
- Main Memory : 64 GB RAM
- Hard Disk Drive: 512 GB Solid State Drive + Regular HDD
- Operating System: 64-bit Windows™ 7 SP1 or higher
- Screen resolution: 1920×1080

#### Accessories:

- Mouse with 2 buttons and a scroll wheel, Internet connection for licensing SCENE

## Autodesk ReCap 2019:

Recommended System Specifications	
OPERATING SYSTEM	Microsoft® Windows® 10 (64-bit) Microsoft Windows 8 (64-bit); Microsoft Windows 7 Enterprise, Ultimate, or Professional (64-bit) <sup>1</sup>  <sup>1</sup> Please note that your OS must be updated with <u>Service Pack 1 (SP1)</u> in order to install ReCap.
CPU TYPE	2.0 gigahertz (GHz) or faster 64-bit (x64) processor
MEMORY	8 GB or more RAM
DISPLAY RESOLUTION	1600 x 1050 or higher true color
DISPLAY CARD	OpenGL 3.3 capable workstation-class graphics card with 1 GB or greater graphics memory
BROWSER	Google Chrome™ - latest version

## Autodesk 3DS Max:

Software	
OPERATING SYSTEM	Microsoft® Windows® 7 (SP1), Windows 8, Windows 8.1, and Windows 10 Professional operating system
BROWSER	Autodesk recommends the latest version of the following web browsers for access to online supplemental content: · Microsoft® Edge · Google Chrome™ · Microsoft® Internet Explorer® · Mozilla® Firefox®

Hardware	
CPU	64-bit Intel® or AMD® multi-core processor with SSE4.2 instruction set
GRAPHICS HARDWARE	Refer to <u>3ds Max Certified Hardware</u> for a detailed list of recommended systems and graphics cards
RAM	4 GB of RAM minimum (8 GB or more recommended)
DISK SPACE	6 GB of free disk space for install
POINTING DEVICE	Three-button mouse

## SolidWorks 2018:

- Windows® 7 or newer (64-bit)
- Dual core CPU; Quad core recommended
- 8GB RAM; 16GB recommended
- 2GB free disk space; 5GB recommended
- 2GB or more GPU RAM; 4GB recommended
- NVIDIA® graphics card: NVIDIA Quadro®/NVIDIA
- GeForce®/Tesla™ with at least NVIDIA Kepler™ chip;
- Dual-GPU setup with at least NVIDIA Maxwell™ cards for the best experience
- NVIDIA driver version 385.41 (or newer) recommended
- NVIDIA driver support for CUDA® 9.0 or newer required

- HDR Light Studio connection: HDR Light Studio v5.3.3 or newer, except v5.4
- 4GB of video memory or more required for the Denoiser feature

## **GeoMagic Design X; 64-bit Edition**

### OS

- Windows 7
- Windows 8
- Windows 10

### CPU

- Intel® and AMD® processors with a minimum 2 GHz clock speed\*
- Recommended: Multiple core processors. Hyperthreading and clock speeds above 3 GHz can be beneficial but should be paired with a good balance of cores.

### RAM

- Minimum: 8 GB

### Hard Disk

- 30 GB or more recommended
- Temporary file cache requires about 3 GB free disk space for every 100 million points
- Recommended: a SSD with more than 256GB of space or a 10000 RPM HDD
- Recommended for 3D Scanning products: using multiple hard drives and assigning one as a "cache" drive for temporary storage and paging files and assigning the other for the operating system

### Display

- 32-bit true color required
- Minimum resolution: 1280 x 960
- Recommended resolution: 1280 X 1024 or higher

### GPU

Design X and Control X recommended graphics cards:

Recommended: Dedicated (Non-Integrated) Graphics Card that meets the criteria below:

- Video Card RAM: 2GB or More
- Video Card Framework: Must support OpenGL 4.0 or above
- Series: NVIDIA Quadro
- Control, Wrap and Capture recommended graphics cards

Recommended: Dedicated (Non-Integrated) Graphics Card that meets the criteria below:

- Video Card RAM: 2GB or More
- Video Card Framework: Must support OpenGL 4.0 or above
- Series: NVIDIA Quadro

## Appendix B: Learning Outcome Manual:

### General Template Info for Exhibit:

#### **3D printed model**

- Focus on Physical Learning Outcomes
  - Visitors will be able to:
    - **Identify specific architectural components commonly represented within Puebloan architecture**
      - The specific architectural features will be chosen from the following list:
        - Construction Material (adobe vs. Stucco)
        - Vigas
        - Latillas
        - Ramadas
        - Canales
        - Niches
        - Splash Boards

#### **iPad**

- Focus on Cultural and Spiritual Learning Outcomes
  - Visitors will be able to:
    - **Recognize that and explain how Puebloan architecture often embodies community, spirituality, and reactive beliefs and values.**
- Focus on Contemporary Influence
  - **Recognize that and explain how contemporary Puebloan architecture has a base in traditional design but has changed as modernized worldviews become more prevalent.**
    - *This is a trans-site-al learning objective*

#### **Touch table**

- Focus on specific site architectural features composition, purpose, and creation.
  - Visitors will be able to:
    - **Identify the composition, uniqueness, and architectural purpose for each of specific site's features outlined through the physical learning outcomes.**

## -----Learning Outcome Illustrations for Each Site-----

### Old Zuni Mission (Zuni Pueblo):

- The Zuni Mission was the main focus of our prototype development and therefore we fully developed learning outcome applications for this location.

### **3D printed model**

- Main Focus
  - Physical architectural features of the Old Zuni Mission
- Establish learning outcomes
  - Visitors will be able to:
    - i. Identify vigas
    - ii. Identify latillas
    - iii. Identify adobe
    - iv. Identify canales

### **iPad**

- Main Focus
  - Brief History
  - Community and Spirituality
  - Contemporary Influence
    - Change over time
- Establish SPECIFIC learning outcomes
- Visitors will be able to:
  - Develop a brief knowledge of Zuni history focusing on the Old Zuni Mission.
  - Community / Spiritual / Cultural
    - Recognize that the Zuni Mission is the center of the Zuni Pueblo which holds cultural, spiritual, and symbolic significance to the tribe as the physical centers often reflect the spiritual centers
    - Recognize that the space around the Mission holds spiritual importance as it is representative of the life and memories of the people that live there
    - Recognize that Puebloan architecture is reactive to its environment rather than static.
      - This is represented through the mural as it shows the Puebloan experience with Christianity and the Puebloan response to social change.
    - Recognize that the Mission is considered a sacred ancestral site as members of the Pueblo are buried underneath.

- Contemporary Influence
  - Recognize that the Old Zuni Mission stayed relatively in the center throughout history
  - Recognize that the style of the Mission stayed the same through renovations and material changes
  - The contemporary model of the Old Zuni Mission has its basis in traditional Puebloan architecture

### **Touch table**

- Establish focus
  - Purpose of physical architectural features for each site
  - Composition and Creation of physical architectural features for each site
- Establish learning outcomes
  - Visitors will be able to identify that:
    - Vigas are used to create support and structure for the roof.
    - Latillas are support by the vigas and make up a more solid support for the roof.
    - The building was originally built mainly from adobe. However, following deterioration the adobe was reinforced with stucco cement.
    - Capstones are put on the walls to prevent them from eroding.
    - Canales serve as functional water management systems to drain water from the flat roofs.
  - Composition and Creation
    - Vigas are made from pine
    - Latillas are made from pine
    - Canales are made from pine
    - Adobe is made with mud and straw
      - Stucco cement is a mix of sand, cement, lime, and water. Animal or plant fibers are often added for additional support



### Isleta Head Start Building (Isleta Pueblo):

- Due to our visit to the Isleta Head Start Building we were able to partially complete the learning outcome applications for this site.

### **3D printed model**

- Main Focus
  - Physical architectural features of each site
- Establish learning outcomes
  - Visitors will be able to:
    - i. Identify vigas
    - ii. Identify adobe

### **iPad**

- Main Focus
  - Brief History
  - Community and Spirituality
  - Contemporary Influence
    - Change over time
- Establish SPECIFIC learning outcomes Visitors will be able to:
  - Develop a brief knowledge of Isleta history focusing on the Isleta Head Start Preschool
  - Community / Spiritual / Cultural
    - Recognize that the Isleta Head Start Building's center room and corridor design are influenced by solstice patterns collinearly.
    - Recognize that the Islet Head Start has rounded hallways to overcome institutionalized feel of typical architecture.
    - Recognize that the grade level hallways of the Isleta Head Start spatially move counter-clockwise to represent migration of the Isleta.
    - Recognize that the Isleta Head Start's center room floor design has the color scheme of a little island to represent the meaning of Isleta – which is little island.
  - How has the building been influenced by traditional Puebloan Contemporary Influence
    - architecture?
      - What has stayed the same and what has changed?

### **Touch table**

- Establish focus
  - Purpose of physical architectural features for each site
  - Composition and Creation of physical architectural features for each site
- Establish learning outcomes
  - Visitors will be able to identify that:
    - Vigas are modernized and used primarily for aesthetic purposes
    - The adobe used is fake (faux-doe). This is more structurally sound material made to look similar to adobe.
  - Composition and Creation
    - Vigas are made from steel
    - Adobe is made with concrete with paint

### **Four Remaining Sites:**

- Sky City Cultural Center and Haak'u Museum (Acoma Pueblo):
- Poeh Center (Pojoaque Pueblo):
- Tessie Naranjo Residence (Santa Clara Pueblo):
- Owe'neh Bupingeh Preservation Project (Ohkay Owingeh Pueblo):

### **3D printed model**

- Establish focus
  - Physical architectural features of each site
- Establish learning outcomes
  - Visitors will be able to answer:
  - Which architectural features from the following list are present in this building?
    - i. Adobe
    - ii. Vigas
    - iii. Latillas
    - iv. Ramadas
    - v. Canales
    - vi. Niches
    - vii. Splash Blocks
    - viii. Physical Location

## **iPad**

- Establish focus
  - Visitors will be able to identify:
  - Brief History
  - Community / Cultural / Spiritual
    - What is the idea of this building and the space around it?
    - How do the tribal values intersect with the architecture?
    - Are they more respective of the world or local view?
    - Is there any interior Imagery or objects that represent cultural history, values, or change?
  - Contemporary Influence
    - How has the building been influenced by traditional Puebloan architecture?
      - What has stayed the same and what has changed?

## **Touch table**

- Establish focus
  - Visitors will be able to identify:
  - What is the purpose of physical architectural features for this site?
  - What is the composition and creation process of physical architectural features for this site?
    - How / Why is it unique?

## Appendix C: iPad Storyboard:





---

Spain established New Mexico as a province in 1598.

In 1610 the provincial capital of Santa Fe was established.

Franciscan missionaries were sent out to build missions and churches in the different Pueblos, one Friar was sent to the the Zuni Pueblo of Halona in 1629.



---

The Zuni Mission was established in 1630. The Mission was named Nuestra Señora de Candelaria de Halona (Our Lady the Light).

It was originally a small adobe convento that housed a priest, a few soldiers, and other Mission personnel.

The Mission church was completed in the 1660s.

Above is an early depiction of the Mission.



The Mission was partially burned and the Priest was killed during the Pueblo Revolt of 1680.

The revolt was lead and orchestrated by Po'Pay of the Ohkay Owingeh Pueblo. A commemorative statue of him can be seen on the left.

The Zuni left and gathered on the sacred mountain Dowa Yalanne, where they had sought shelter and protection in the past.

Later, in the 1690s the Spanish returned and re-established their presence.



The Zuni returned and instead of settling in separate settlements, they all chose to live in Halona. This became known as the Zuni Pueblo.

The Franciscan friars returned and the Mission was rebuilt in 1705.

Two bell towers and a balcony were added to the building, they later fell and were not rebuilt.

It was renamed Nuestra Señora de Guadalupe (Our Lady Guadalupe).

A photo of the Mission from 1873 can be seen on the left.



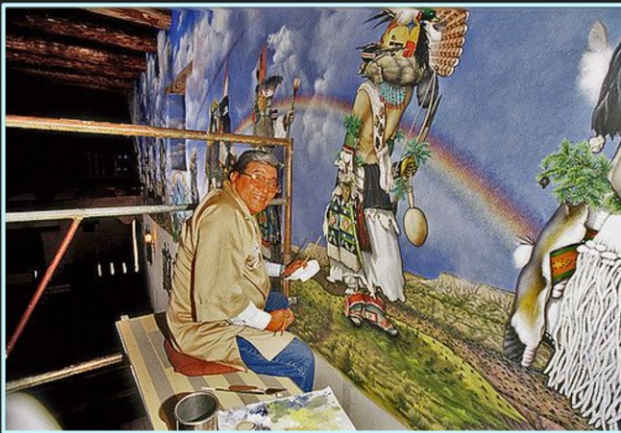


In 1776 Pacheco altar was built. An early photo of the alter can be seen above.

Due to natural deterioration, the Mission was rebuilt again in 1780.

After Mexico won independence from Spain in 1821, the Franciscan friars left and the Mission was largely abandoned

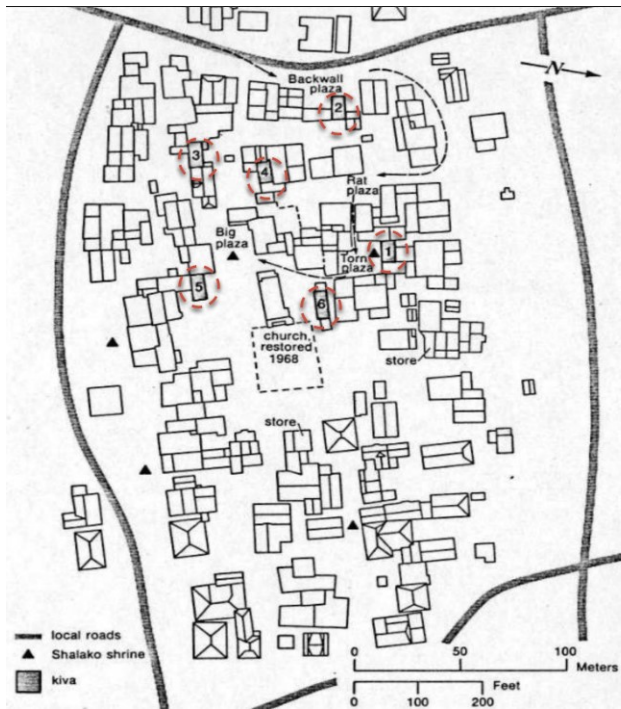
The Mission saw renovation in 1921 when Priests were reassigned there.



During the 1960s, a Partnership between the Catholic Diocese of Gallup, the Zuni Tribe, and the Bureau of Indian Affairs gave permission and funding for the Zuni Mission to be renovated and repaired.

One of the most pronounced additions were the murals located on the north and south interior walls of the Mission. These were painted by Alex Seowtewa and his two sons. A photo of Alex Seowtewa can be seen on the left. The mural includes 24 figures of different Kachinas and tribal leaders. Later on, additional panels of crops, birds, and animals were added. A kiva alter was also completed.

Adding the murals was approved after Alex spoke to two elders who had recalled that there were once Kachinas painted on the walls almost a century ago when they were children and would play in the church.



This map shows the location of kivas, shops, and the Zuni Mission in 1972. Prior to 1630, the site of the church was a trash dump. When the church was built, the village slowly constructed its way around the radius of the building, securing the Mission in the center of the village. Here, the Mission can be seen surrounded by kivas. This location is a sacred place for the majority of the Zuni People who still practice their traditional ceremonies adjacent to the Mission.

revised from Nat. Park Service, Histl. Amer. Buildings Survey: map for 1972.  
 Fig. 3. Central (original) portion of Zuni Pueblo. Kivas are numbered: 1, Wall kiva; 2, Backwall kiva; 3, Parched Corn kiva; 4, Dung kiva; 5, Brain kiva; 6, Little Group kiva. Arrows show route taken by kachina dancers.



The Old Zuni Mission is currently not in use and it is undergoing funding for renovation work.

Whether or not the renovation will be completed, as well as the process behind the renovation, is still being decided.



# Community and Spirituality

The Old Zuni Mission along with the nearby cemetery and ceremonial plazas occupy the physical center of the Zuni Pueblo.



This location holds symbolic significance to the people as the physical centers typically reflect the tribe's spiritual centers as well as the importance of community.

**Proprietary Materials**



**Proprietary Materials**

Some members of the Zuni Pueblo consider the church a sacred site because ancestral members of the Pueblo are buried underneath as well as in the cemetery in front. As a result, the church is referred to as a “hallowed ancestral site.”

These murals reflect the Zuni ability to respond to their environment while maintaining a strong traditional influence in their everyday architecture and values.

The inside murals display a dedication to both the Catholic Church and Zuni traditions, which coexist for many of the Zuni People.

**Proprietary Materials**



The space around the mission holds spiritual importance as it is representative of the life and memories of the people that live there.

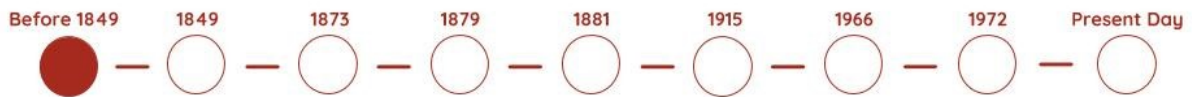
Many traditional religious ceremonies continue to be held in the open, communal plazas in the pueblo core, often involving processions through the pathways that connected them.

# Contemporary Influence

The original version of the Mission was built in 1629

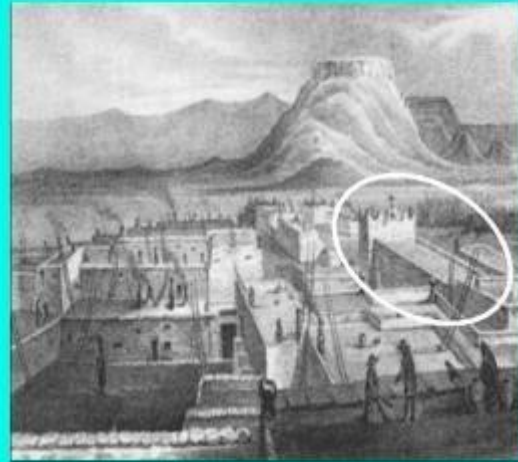
Here it is possible to see the convento that was built in 1630

The Mission church was then built next to it and was completed in 1630



This picture depicts the third edition of the mission. It was rebuilt prior in 1705 and 1780.

Despite the renovations, the architectural style of the mission and attached convent remained the same



First Photograph of Old Zuni Mission

The adobe bricks that make up the second edition of the mission begin to deteriorate





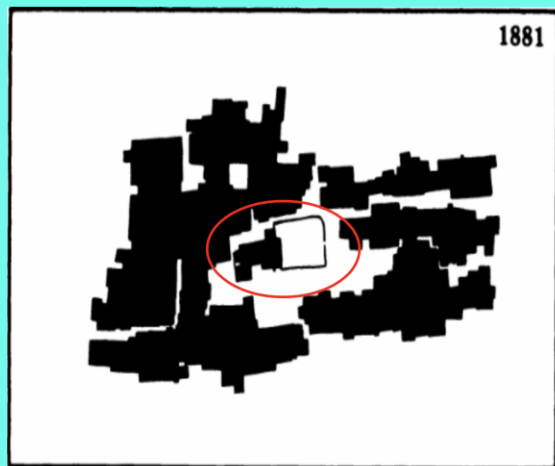
## Back view of the Old Zuni Mission

The natural adobe bricks that make up the mission and convent continue to break down.

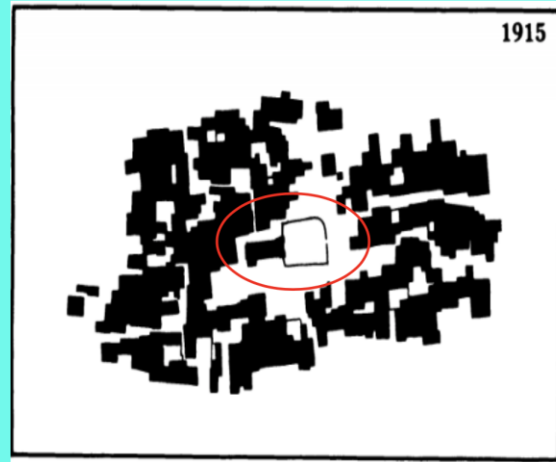


This image depicts the location of the Old Zuni Mission relative to the other buildings in the Pueblo.

The centralized location represents the communal center of the Zuni.



As local buildings expand and spread, the mission remains positioned in the physical center of the Pueblo.



The mission had been renovated once again in 1921 using similar architectural materials. This version did not have an attached covent.

This image depicts a deteriorated 1921 model right before the mission was again rebuilt in 1966.



The building remains centralized.

The Mission is restored with more structurally sound materials, such as stucco cement but the same look in 1966.



The stucco cement is currently breaking down.

While the location, shape, and look mission stayed the same, the architectural practices and materials changed since the first edition.





## Appendix D: Touch Table Storyboard:

The storyboard is divided into two main horizontal sections. The top section features a large circular menu on the left with a central icon of a Zuni tower and segments for 'Zuni', 'Acoma', 'Pojoaque', 'Ohkay', 'Owingeh', 'Santa Clara', and 'Isleta'. To its right is a large image of a Zuni tower. The bottom section is titled 'Zuni' and contains a smaller circular menu with segments for 'Adobe', 'Explore', 'Canals', 'Back', 'Vigas', and 'Latillas'. Below this menu is a small image of a tower. To the right of the menu is a text block about 'Adobe' with a 'Learn More?' button. Further right is a section titled 'Explore the Feature!' with an image of a tower wall cross-section.

**Zuni**

**Adobe**

Adobe bricks make up the base layer of the wall.

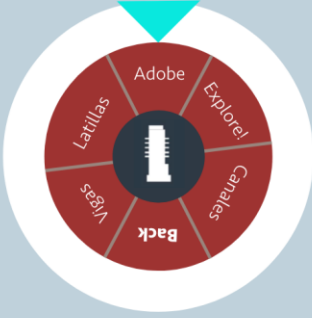
Over time, this adobe deteriorated and was covered with a layer of Stucco Cement.

Stucco is a mix of sand, cement, lime, and water with animals and plant fibers often added for support.

[Learn More?](#)

**Explore the Feature!**





## Zuni

### More on Adobe!

The adobe was covered with stucco cement mixed with gypsum. This was done in order to shield the adobe from the elements. Most stucco cement used to cover historical buildings is made with lime. Unfortunately the gypsum mix is causing the building to fall apart prematurely.

Back

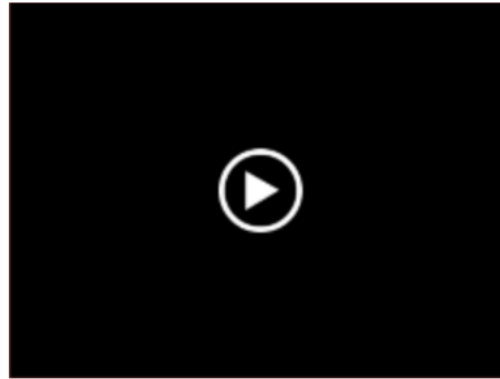
### Explore the Feature!



## Zuni

Interact Inside!

Interact Outside!

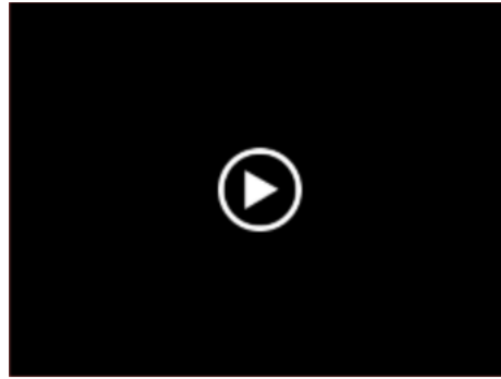


## Zuni



Interact Inside!

Interact Outside!



## Zuni



### Canales

The canales on the Old Zuni Mission are made out of pine. They are used to direct excess water off of the building.

### Explore the Feature!



Learn More?



## Zuni



### More about Canales!

The pine used to create the canales were dragged by horses from over 25 miles away at the request of the Mission's friars.

Back

### Explore the Feature!



## Zuni



### Vigas

The vigas on the Old Zuni Mission are made out of pine.

They are used to support the roof above.

Learn More?

### Explore the Feature!



## Zuni



### More about Vigas!

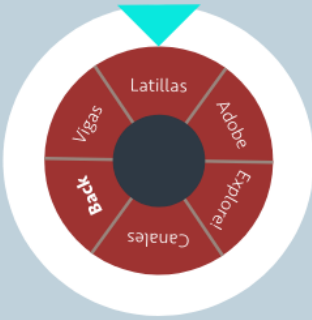
The pine used to create the vigas was dragged by horses from over 25 miles away.

[Back](#)

### Explore the Feature!



## Zuni



### Latillas

The latillas on the Old Zuni Mission are made out of red cedar.

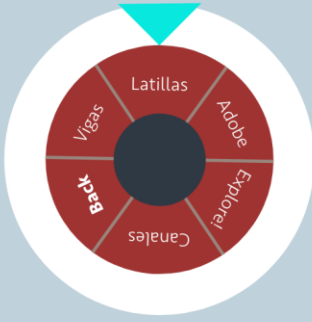
Along with the vigas, they are used to add additional support for the roof.

[Learn More?](#)

### Explore the Feature!



## Zuni



### More about Latillas!

The red cedar used to create the latillas were dragged by horses from over 25 miles away at the request of the Mission's friars.

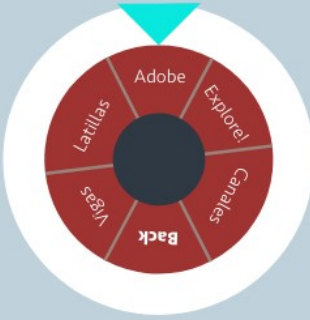
### Explore the Feature!



Back



## Isleta



### Adobe

The "adobe" on the Isleta Head Start Building is considered "Faux-dobe"

This is more structurally sound material made to look like adobe for aesthetic reasons.

[Learn More?](#)

### Explore the Feature!



## Isleta



### Vigas

The vigas in the Isleta Head Start Building are made of steel and painted red.

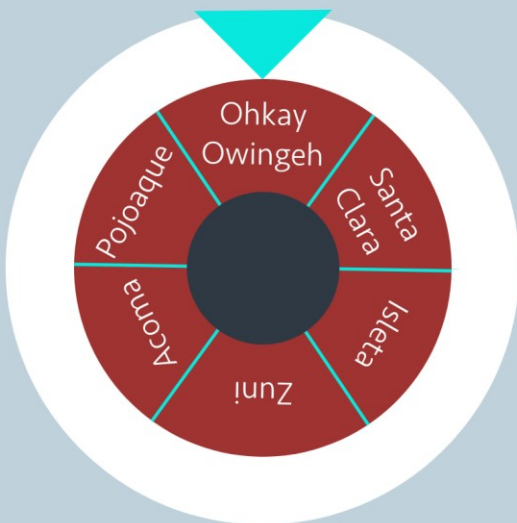
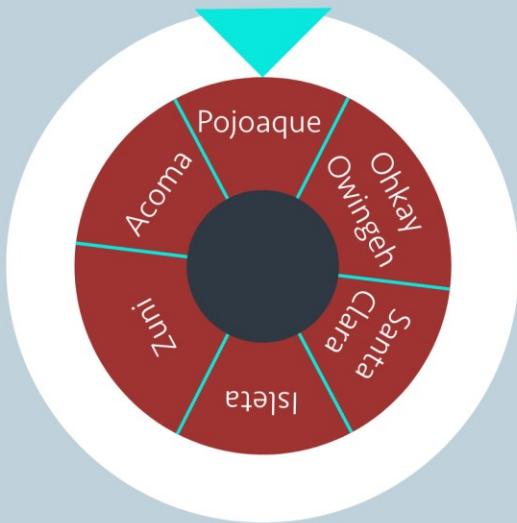
Rather than serve a structural purpose, they are present for aesthetic purposes.

[Learn More?](#)

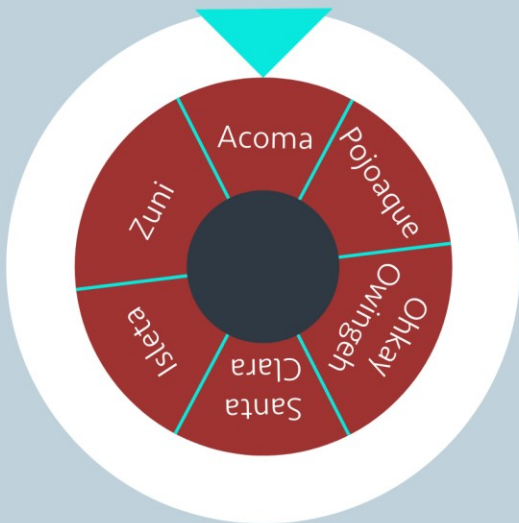
### Explore the Feature!











**No Image Available**



Appendix E: Costs List:

<b>Item</b>	<b>Individual cost</b>	<b>Number Needed</b>	<b>Total cost</b>	<b>Notes</b>
Platform 46 Coffee Multitouch Table	\$12,950 including computer	1	\$12,950	Larger, more expensive models exist
Android Studio	\$25 per year for official app	1	\$25 Annual	Unity is a free alternative
3D Printed Models Approximately	\$70 for Zuni Print	6 Sites Total	\$420	Requires both PLA and PVA filament. Will vary by site.
iPad / Tablet	\$100-400* *Prices Vary by model and vendor	6	\$600-2,400	Consider Tablet donations and discounts for educational purposes
FARO Scene	30 Day Free trial; \$600 Educational License	1	\$600	
FARO Scene - Video Pro plugin	7-Day Free trial, Single user license: \$1,165 excluding tax	1	\$1,165	Has free version with watermark.
AutoDesk ReCap	Free as Student for 3 years; Single License \$305.00	1	\$305.00	
SolidWorks	\$86 per Year for student edition	1	\$86 Annual	
Geomagic X Design	15 Day Free Trial; Single License \$19,950	1	\$19,950*	*Only Used for Mesh Model
AutoDesk 3DS Max	Free as Student for 3 years; Annual License: \$1,505.00	1	\$1,505.00*	*Only Used for Mesh Model
<b>Estimated Total:</b>			<b>\$16,751</b>	(* <i>\$38,206 with mesh</i> )

## Appendix F: Guided Survey with College Students:

The purpose of this study is to examine how well our exhibit prototype communicates the intended learning outcomes. Additionally, it will provide insight on the intuitiveness of our exhibit.

Discussion Chair:

Discussion Secretary:

Date of Study:

Age: \_\_\_\_\_

Gender: \_\_\_\_\_

- 1.) On a scale of 1(did not know any)-5(knew all of it), how much of the information presented through the exhibit did you already know?

1

2

3

4

5

**Learning Outcome:** *Visitors will be able to identify specific architectural components commonly represented within Puebloan architecture*

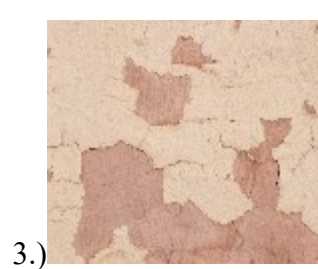
- 2.) Based on the pictures below, write the number corresponding to the correct physical features:

a.) Vigas: \_\_\_\_\_

b.) Latillas: \_\_\_\_\_

c.) Adobe: \_\_\_\_\_

d.) Canales: \_\_\_\_\_



**Learning Outcome:** *Visitors will be able to identify the composition, uniqueness, and architectural purpose for each specific site's physical features outlined in the 3D model*

3.) What are the latillas on the Zuni Mission made out of?

- a. Japanese Oak
- b. Red Cedar
- c. Blue Spruce
- d. Indian Rosewood

4.) What is the typical function of the following?

Viga: \_\_\_\_\_

Canale: \_\_\_\_\_

**Learning Outcome:** *Visitors will be able to recognize that and explain how contemporary Puebloan architecture has a base in traditional design but has changed as modernized worldviews become more prevalent*

5.) Where was/is the Old Zuni Mission located within the community boundaries during its renovation in 1881 versus current day respectively?

- a. Center, The North Border
- b. The East Border, The West Border
- c. Center, Center
- d. The West Border, The North Border

6.) What material was used to construct the Old Zuni Mission in 1629 and its current renovation respectively?

- a. Wood, Ceramic
- b. Adobe, Stucco Cement
- c. Clay, Concrete
- d. Limestone, Bricks

**Learning Outcome:** *Visitors will be able to recognize that and explain how Puebloan architecture often embodies community, spirituality, and reactive beliefs and values*

- 7.) Why is the Old Zuni Mission's placement important to local culture? Circle all that apply.
- a. The physical centers of a community often represent the spiritual centers as well.
  - b. It was oriented towards the north to represent the spring equinox.
  - c. Ancestral members of the Zuni Pueblo are buried beneath the church.
  - d. The placement is not important to local culture.

8.) Do you feel you the exhibit was set up in a way that was easy to understand and operate?

9.) What is something new you learned about Puebloan architecture? What further information do you wish was available?

10.) Is the exhibit physically appealing? What pieces could change to make it more exciting?

## Appendix G: Guided Survey Results:

**Learning Outcome:** *Visitors will be able to identify specific architectural components commonly represented within Puebloan architecture*

**Learning Outcome:** *Visitors will be able to identify the composition, uniqueness, and architectural purpose for each specific site's physical features outlined in the 3D model.*

**Learning Outcome:** *Visitors will be able to recognize that and explain how Puebloan architecture often embodies community, spirituality, and reactive beliefs and values.*

**Learning Outcome:** *Visitors will be able to recognize that and explain how contemporary Puebloan architecture has a base in traditional design but has changed as modernized worldviews become more prevalent.*

User List:	Age:	Gender:	Exhibit Time (min):	1) Prior Knowledge (1-5):	2) Physical Features: Vigas	2) Latillas	2) Abobe	2) Canales	PHYSICAL Outcome 1: 2
Visitor 1	20	Male	21	2	Yes	No	Yes	No	50%
Visitor 2	20	Male	21	1	No	Yes	Yes	No	50%
Visitor 3	19	Male	24	1	Yes	Yes	Yes	Yes	100%
Visitor 4	20	Male	24	2	Yes	Yes	Yes	Yes	100%
Visitor 5	20	Male	13	1	Yes	Yes	Yes	Yes	100%
Visitor 6	20	Female	13	1	No	No	Yes	Yes	50%
Visitor 7	20	Male	13	2	Yes	Yes	Yes	Yes	100%
Visitor 8	19	Female	14	3	Yes	Yes	Yes	Yes	100%
Visitor 9	21	Male	14	1	Yes	Yes	Yes	Yes	100%
Visitor 10	21	Male	14	3	Yes	Yes	Yes	Yes	100%
Visitor 11	20	Male	14	2	Yes	No	Yes	Yes	75%
Visitor 12									
AVERAGE			16.8181818						84%

User List:	3) Latilla Material:	4) Typical Function: Vigas	4) Typical Function: Canales	(PHYSICAL Outcome 2: 3-4)
Visitor 1	Yes ▾	Vigas Are Vertical	part of foundation	0%
Visitor 2	Yes ▾	Support	Roof	100%
Visitor 3	Yes ▾	Support Roof	It does something	66%
Visitor 4	Yes ▾	Large Horizontal beams that suport the roof	Direct water off the roof	100%
Visitor 5	Yes ▾	Roof Holding	Water Movement	100%
Visitor 6	Yes ▾	Top of building, holds roof	Gets rid of water	100%
Visitor 7	Yes ▾	Roof Support	Water Movement	100%
Visitor 8	Yes ▾	Support the roof	Roofing to protect against the elements	66%
Visitor 9	No ▾	Supports Roof	Move water off roof	66%
Visitor 10	No ▾	Support	Draining Water	66%
Visitor 11	Yes ▾	Support structure	direct water flow	100%
Visitor 12	▾			
AVERAGE				79%

User List:	5) Where's the Mission?	6) Zuni Material:	Influential (5-6)	7) Placement Importance:	Cultural Outcome: 7
Visitor 1	Yes	Yes	100%	a, c	100%
Visitor 2	Yes	Yes	100%	a, b, c	100%
Visitor 3	No	Yes	50%	a, c	100%
Visitor 4	Yes	Yes	100%	a	50%
Visitor 5	No	Yes	50%	a, c	100%
Visitor 6	No	Yes	50%	a, c	100%
Visitor 7	No	Yes	50%	c	50%
Visitor 8	Yes	Yes	100%	a	50%
Visitor 9	Yes	Yes	100%	a, b, c	100%
Visitor 10	Yes	Yes	100%	a	50%
Visitor 11	Yes	Yes	100%	a, c	100%
Visitor 12					
AVERAGE			82%		82%

User List:	8) Exhibit Ease?	9) Learn Something New?	10) Appealing?	Observer Notes	Suggestions
Visitor 1	Yes, Very helpful and informative. There was plenty to do and it was interactive	How sacred the OZM is. I wish I knew more about their interactions and the Spaniards	Yes. Maybe more sound. No exam. More questions about things that can be changed	Struggled to identify button on the Model, and how to correctly use the buttons.	Switch lights and buttons on 3D model
Visitor 2	Yes, except when the exhibit broke, also the tv stuff was slightly complicated	What all of the things on the model are	Yes, easier to use buttons	Navigating into site information on touch table was not clear (clicking on image). Liked pretty vibrant colors! Enjoyed 3D model burned wood words	
Visitor 3	yes	I learned that many structures are made with adobe. I wish there was more information on other famous architectures	Yes. I think they should change the buttons with the LEDs	Went to touch table first, then 3D model. DROPPED THE TANGABLE. Thought ground around the mission was red paint	Voice Overs in the videos
Visitor 4	yes	Materials used to build the zuni mission. Would like to know more about construction methods, how materials are processed used and made	Yes, Maybe the touch table--Actually a touch table, some things looked interactive but did nothing	Interactive responsiveness was important, wanted more red button. iPad brief history was too fast?	
Visitor 5	Yes	There are people beneath it (dead)	Make it even bigger, so you can walk in	Struggled to find buttons	
Visitor 6	Yes, but I think the videos should be slides so users can go through as fast / slow as they want	There are people buried under it. More information about materials and who is buried there	Yes, I liked the touch table	Engaged in deep conversation on Zuni religion history and influence	
Visitor 7	Yes, couldn't find the buttons on the model	There are people beneath it they are dead	Yes	Once there were more than 2 people per section, they switched to other sections	
Visitor 8	Yes	The model looks a little fragile	No Answer	Struggled to find buttons. Was confused by ground around the mission. Didn't know ground was real thing	
Visitor 9	Maybe	They Existed	Yes, more to interactive	Unsure whether to touch image on touch table, and asked how to go back.	Defuse the LEDs!
Visitor 10	Oh for sure	I didn't learn anything because I've been paying attention to presentations during the last two terms	Yes, make the pieces more durable. Colored models would be cool	Stress tested the 3D model buttons 5025 cycle	
Visitor 11	It was, other than android emulation	Canals direct water flow. I did not know there was water in the desert	It is appealing but I think there could be more indication to touch the picture of the mission	Understood that the buttons were red!	Voice overs in the videos
Visitor 12					
AVERAGE					



## Appendix H: Focus Group Discussion with Pueblo Site Liaisons:

Discussion Chair:

Discussion Secretary:

Date of Study:

A. Objective:

- a. The purpose of this study is to gauge success in regard to the cultural appropriateness of our exhibit. Through this focus group, our goal is to determine if our exhibit accurately depicts the various aspects of Puebloan architecture such as specific architectural feature modelling and the cultural reasoning behind these features.

B. What this focus group will educate iD+Pi on / General Notes:

- a. This focus group will allow iD+Pi to gauge the cultural appropriateness of the exhibit. Since this exhibit serves to depict cultural architecture, it is important that a significant amount of information comes directly from those whom are being depicted.
- b. Additionally, this focus group will allow iD+Pi to obtain and apply indigenous feedback to the exhibit before the final product is created.
- c. Demographic information will be requested upon entry of the guests. This will allow them to opt out of questions they feel uncomfortable with. The demographic information will include information regarding age, gender, Pueblo affiliation, etc.

C. Source of information:

- a. Puebloan representatives will be used in this focus group because they will provide the most educated insight on how the exhibit could be made more culturally appropriate. Ideally, a member of the respective Pueblo will provide information on each site, allowing an accurate representation of material. Additionally, sensitive material that was otherwise unknown can be filtered out of the exhibit.

Guiding Questions:

- 1) What do you hope for in an exhibit representing Puebloan architecture?
- 2) What are your initial thoughts on exhibit?
- 3) Does this exhibit accurately represent your respective tribes? (Depending on digital design progress: How would you like an exhibit to accurately represent your respective tribes?)
- 4) Would you change anything the way the exhibit represents anything?
- 5) With education in mind, do you feel this exhibit sufficiently communicates Puebloan architecture?

## Appendix I: Focus Group Discussion with Museum Exhibit Visitors:

Discussion Chair:

Discussion Secretary:

Date of Study:

### A. Objective:

1. Assess exhibit effectiveness relative to learning outcomes
  - a) An important part of our project is determining how effective it was in portraying the initial goals relative to cultural accuracy and the learning outcomes. This focus group will serve to give them an idea of how our prototype impacted the audience. With this information they will be able to offer changes that can be made to the prototype to create a better final exhibit.

### B. What this focus group will educate iD+Pi on / General Notes:

1. This focus groups will give iD+Pi insight on visitor's initial thoughts are on our exhibit. This will help them to gauge the attractiveness of the prototype to the average cultural center visitor.
2. This focus group will show iD+Pi if the prototype was intuitive to the average visitor at the cultural center. This is important for them to gauge the clarity of the prototype.
3. This focus group will show the educational outcomes of the exhibit on museum visitors. This is important to them because they hope to learn how their findings from this study compare to the developed learning outcomes, and if they were effective.
4. Since a major goal of this focus group is to gauge the intuitiveness, all questions will be assuming that visitors walked through the exhibit themselves. Since the real exhibit will not offer personal help, this will give us the best analysis regarding how the exhibit will actually function.
5. There as much time as necessary to go through the exhibit. Afterwards, this data will be recorded to determine an average amount of time visitors spent in the exhibit
6. Demographic information will be requested upon guest arrival to focus group. This will allow them to opt out of answering any questions they are not comfortable with. Demographic information will include age, gender, residence location, etc.

C. Source of information and why:

1. The IPCC visitors will allow us to determine the educational impact of our exhibit on the people that will be viewing it. With this, we will be able to offer suggestions on the creation of the final project to implement the learned weaknesses of our prototype.

D. Necessary Questions:

1. What are your initial thoughts on exhibit?
2. Is the exhibit appealing. If so, How? If not, How?
3. Is the exhibit design and use intuitive?
4. What do you feel you have learned from the exhibit?

E. On a scale of 1(did not know any)-5(knew all of it), how much of the information presented through the exhibit did you already know?

1                      2                      3                      4                      5

**Learning Outcome:** *Visitors will be able to identify specific architectural components commonly represented within Puebloan architecture*

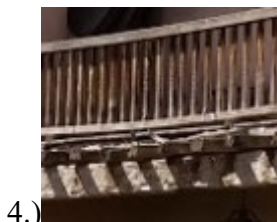
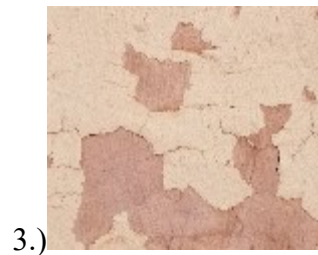
5. Based on the pictures below, write the number corresponding to the correct physical features:

a) Vigas: \_\_\_\_\_

b) Latillas: \_\_\_\_\_

c) Adobe: \_\_\_\_\_

d) Canales: \_\_\_\_\_



**Learning Outcome:** *Visitors will be able to identify the composition, uniqueness, and architectural purpose for each specific site's physical features outlined in the 3D model*

3.) What are the latillas on the Zuni Mission made out of?

- e. Japanese Oak
- f. Red Cedar
- g. Blue Spruce
- h. Indian Rosewood

4.) What is the typical function of the following?

Viga: \_\_\_\_\_

Canale: \_\_\_\_\_

**Learning Outcome:** *Visitors will be able to recognize that and explain how contemporary Puebloan architecture has a base in traditional design but has changed as modernized worldviews become more prevalent*

5.) Where was/is the Old Zuni Mission located within the community boundaries during its creation in 1629 versus current day respectively?

- e. Center, The North Border
- f. The East Border, The West Border
- g. Center, Center
- h. The West Border, The North Border

6.) What material was used to construct the Old Zuni Mission in 1629 and its current renovation respectively?

- e. Wood, Ceramic
- f. Adobe, Stucco Cement
- g. Clay, Concrete
- h. Limestone, Bricks

**Learning Outcome:** *Visitors will be able to recognize that and explain how Puebloan architecture often embodies community, spirituality, and reactive beliefs and values*

- 7.) Why is the Old Zuni Mission's placement important to local culture? Circle all that apply.
- e. The physical centers of a community often represent the spiritual centers as well.
  - f. It was oriented towards the north to represent the spring equinox.
  - g. Ancestral members of the Zuni Pueblo are buried beneath the church.
  - h. The placement is not important to local culture.

E. Additional Questions:

1. What was your favorite part of the exhibit?
  - a) It will be important for us to know the most successful parts of our prototype.
2. What was your least favorite part?
  - a) We need to assess any pitfalls our prototype may contain so we can recommend changes to the exhibit if necessary.
3. Were there any parts of the exhibit you didn't understand?
  - a) This is an important question because we would like our exhibit to reach all ages, and we need to know whether or not our prototype exhibit is too simplistic or too complex for the average visitor.

# Appendix J: 3D Print Program Settings:

**Color scheme**  
Material Color

- Extruder 1
- Extruder 2
- Show Travels
- Show Helpers
- Show Shell
- Show Infill

1032

**Extruder 1** | **Extruder 2**

Material: Silver Metallic PLA  
Print core: AA 0.4

[Check compatibility](#)

**Print Setup**  
Recommended | Custom

Layer Height: 0.06 0.1 0.15 0.2 0.3 0.4  
Print Speed: Slower | 0.15 | Faster  
Infill: 10%  
 Enable gradual

Generate Support:  Extruder 2  
Build Plate Adhesion:

Need help improving your prints?  
[Read the Ultimaker Troubleshooting Guides](#)

Ready to Save to File

UMSS\_STL Zuni Mission Front  
112.1 x 158.5 x 154.9 mm

**01d 09h 16min**  
35.08 + 3.96m / ~ 27...g / ~ 18.50 + 2.07 \$

[Save to File](#)

**Color scheme**  
Material Color

- Extruder 1
- Extruder 2
- Show Travels
- Show Helpers
- Show Shell
- Show Infill

688

**Extruder 1** | **Extruder 2**

Material: White PLA  
Print core: AA 0.4

[Check compatibility](#)

**Print Setup**  
Recommended | Custom

Layer Height: 0.06 0.1 0.15 0.2 0.3 0.4  
Print Speed: Slower | 0.15 | Faster  
Infill: 10%  
 Enable gradual

Generate Support:  Extruder 2  
Build Plate Adhesion:

Need help improving your prints?  
[Read the Ultimaker Troubleshooting Guides](#)

Ready to Save to File

UMSS\_STL Zuni Viga Side  
257.4 x 113.5 x 103.3 mm

**02d 01h 06min**  
61.06 + 4.66m / ~ 48...g / ~ 32.20 + 2.43 \$

[Save to File](#)

Color scheme  
Material Color

- Extruder 1
- Extruder 2
- Show Travels
- Show Helpers
- Show Shell
- Show Infill

22

Extruder 1 Extruder 2

Material White PLA

Print core AA 0.4

[Check compatibility](#)

Print Setup Recommended Custom

Layer Height 0.06 0.1 0.15 0.2 0.3 0.4

Print Speed Slower Faster

Infill 20%

Enable gradual

Generate Support  Extruder 2

Build Plate Adhesion

Need help improving your prints?  
Read the [Ultimaker Troubleshooting Guides](#)

Ready to Save to File

06h 21min  
3.69 + 2.67m³ / ~ 29 ...1g / ~ 1.95 + 1.40 \$

Save to File

UM55\_STL Large Viga Roof  
182.2 x 94.0 x 4.3 mm

Color scheme  
Material Color

- Extruder 1
- Extruder 2
- Show Travels
- Show Helpers
- Show Shell
- Show Infill

182

Extruder 1 Extruder 2

Material White PLA

Print core AA 0.4

[Check compatibility](#)

Print Setup Recommended Custom

Layer Height 0.06 0.1 0.15 0.2 0.3 0.4

Print Speed Slower Faster

Infill 20%

Enable gradual

Generate Support  Extruder 2

Build Plate Adhesion

Need help improving your prints?  
Read the [Ultimaker Troubleshooting Guides](#)

Ready to Save to File

03h 53min  
2.69 + 0.45m³ / ~ 21 + 4g / ~ 1.42 + 0.24 \$

Save to File

UM55\_STL Zumi Mission Deck  
99.4 x 45.2 x 36.4 mm



Color scheme  
Material Color

- Extruder 1
- Extruder 2
- Show Travels
- Show Helpers
- Show Shell
- Show Infill

Extruder 1 Extruder 2

Material White PLA

Print core AA 0.4

[Check compatibility](#)

Print Setup Recommended Custom

Layer Height 0.06 0.1 0.15 0.2 0.3 0.4

Print Speed Slower Faster

Infill 20%  Enable gradual

Generate Support  Extruder 2

Build Plate Adhesion

Need help improving your prints?  
Read the [Ultimaker Troubleshooting Guides](#)

Ready to Save to File

UMSS\_UM3E\_STL Big Window Wood 115.7 x 152.8 x 23.5 mm

01h 47min  
1.55 + 0.28m / ~ 12 + 2g / ~ 0.82 + 0.15 \$ [Save to File](#)

Color scheme  
Material Color

- Extruder 1
- Extruder 2
- Show Travels
- Show Helpers
- Show Shell
- Show Infill

Extruder 1 Extruder 2

Material White PLA

Print core AA 0.4

[Check compatibility](#)

Print Setup Recommended Custom

Layer Height 0.06 0.1 0.15 0.2 0.3 0.4

Print Speed Slower Faster

Infill 10%  Enable gradual

Generate Support  Extruder 2

Build Plate Adhesion

Need help improving your prints?  
Read the [Ultimaker Troubleshooting Guides](#)

Ready to Save to File

UMSS\_STL Old Zuni Mission Assembly No Shell 150.0 x 65.2 x 62.0 mm

09h 40min  
9.16 + 3.03m / ~ 72 ...4g / ~ 4.83 + 1.59 \$ [Save to File](#)

The image shows the Cura software interface. On the left, a 3D view of a printed object (a cluster of vertical pillars) is shown on a grid build plate. The printer is labeled "Ultimaker 3 Extended". A vertical dimension line indicates a height of 62 mm. The object is identified as "UM3E\_STL Regular Vige" with dimensions "69.5 x 69.5 x 12.4 mm".

The right-hand panel contains the following settings:

- Extruder 1** and **Extruder 2** tabs.
- Material:** White PLA
- Print core:** AA 0.4
- [Check compatibility](#)
- Print Setup:** Recommended / Custom
- Layer Height:** 0.06, 0.1, 0.15, 0.2, 0.3, 0.4
- Print Speed:** Slower / Faster (slider)
- Infill:** 10% (slider),  Enable gradual
- Generate Support:**  Extruder 2
- Build Plate Adhesion:**
- [Need help improving your prints? Read the Ultimaker Troubleshooting Guides](#)
- Ready to Save to File**
- 00h 57min**
- 0.76 + 0.01m / ~ 6 + 0g / ~ 0.40 + 0.00 \$
- [Save to File](#)