INVESTIGATING CULTURALLY-CONTEXTUALIZED MAKING WITH THE NAVAJO NATION

By

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To my family
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<td>ANSEP</td>
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<td>STEAM</td>
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Native Americans are one of the most severely underrepresented ethnic groups in the engineering field. To address their underrepresentation, this study looked to work with the Navajo Nation to design a makerspace for the community. A makerspace is a place where people can learn about engineering through making. This study was guided by two research questions: *In what ways do the Navajo describe the experience of making? How can the Navajo experience of making be integrated to design a culturally-contextualized makerspace?*

To address these questions, data were collected in the form of semistructured interviews. The first research question was addressed by analyzing the data using phenomenography and Maslow’s hierarchy of needs framework. These data were also used in conjunction with the engineering design process to develop the design specifications required to address the second research question.

The results from addressing the first research question are an awareness of the unique ways in which members of the Navajo Nation understand the experience of making. These results helped to inform three design concepts for a culturally-contextualized makerspace, concepts that integrate the unique ways the Navajo Nation
understand the experience of making and are both responsive and respectful to the distinct needs and worldviews of their community. The engineering skills and attitudes developed in such makerspaces have the potential to both strengthen the engineering field and the Navajo Nation.
CHAPTER 1
INTRODUCTION

The goal of this document is to outline the context and motivation for my research project, discuss the current state of relevant literature, present the design and findings of the study, and provide recommendations for future research.

1.1 About the Author

Prior to discussing this project, it is important that I first introduce myself and provide my motivation for choosing this project. My name is Daniel Z. Frank and I grew up on the New Jersey-Pennsylvania border. My family is of European descent, and while I respect the worldview of the Navajo people, it is not one with which I identify. As an undergraduate at Lehigh University, I became involved with engineering education outreach efforts at local schools. Through these efforts, I developed a passion for teaching, which led me to look for teaching positions after I graduated. I applied for Teach For America but was ultimately rejected. While I was disheartened, I did not want to give up on my dream. My older sister, who had previously worked on the Navajo Nation, suggested that I might find a teaching position there. After a successful interview, I soon found myself moving out West.

During the 2010-2011 school year, I taught mathematics and coached soccer for middle school students from the Navajo Nation. While many of my students were extremely gifted in mathematics, very few of them had been exposed to engineering. To help, I organized and ran an afterschool engineering club. At first, I expected that only a few students would be interested in attending, but my expectations were shattered in a positive way when I had large numbers of students showing up.
One of the projects that I presented to the students was an egg drop. Students had to use various materials to make a contraption that would protect an egg from a 2-story fall. For this type of activity, I expected that most of the students would construct a cage that would cushion the egg when it fell or a parachute that would help slow its descent. While these were common designs, one student took a different approach that I had never seen before. Just as a maple seed spins like a helicopter as it falls to the ground, this student made a device that would spin in the same way, allowing it to fall at a slower rate and protect the egg.

After the school year, I moved to Gainesville to start graduate school at the University of Florida. However, while at Florida, the genuine excitement that my students demonstrated in that engineering club motivated me to come back to visit every year. During my visits, I would bring back what I was learning in graduate school (3D printing, robotics, microprocessors, etc.) and I would share it with the students in the form of presentations, demonstrations, and activities.

Over the years, I often thought about the maple seed egg contraption and all of the other marvelous innovations that members of the Navajo Nation would develop if provided the opportunity. When it came time for me to choose a project for my dissertation, I decided that if I was going to devote an enormous amount of time to one endeavor, I wanted the community that I had grown to respect and care about to benefit from it. I understand that it would have been more appropriate for this study to have been conducted by a member of the Navajo Nation, but despite this limitation, I believe that this study has produced useful results. Just like a maple seed, the results of this study are simply a starting point. My goal is that the Navajo Nation will take ownership
of the project and nurture it; leading it to greater and more sustainable initiatives led by the community. While it is impossible to know exactly what shape a tree will take before it has fully grown, whichever way it decides to grow, I know that it will be beautiful.

1.2 Background and Motivation

1.2.1 The Maker Movement

For millions of years, humans have been makers of artifacts, starting with the first stone tools (Wayman, 2012). For nearly all of history, humans have made these artifacts by working with their own hands. The word manufacture itself comes from the Latin phrase, manu factus, which means hand made. However, advancements in technology and the mechanization of manufacturing brought about a shift from making goods by hand to manufacturing them by machines. During the late 19th and early 20th centuries, the decline in artisanship caused by the production of goods by machines (Pevsner, 2005) gave rise to the Arts and Crafts Movement. This movement rejected these new, poorly crafted goods for more traditional ones made by skilled hands. This movement lasted until about World War I when manufacturers had begun to perfect the art of mimicking artisan craftsmanship in their mass-produced goods (Sivek, 2011).

For many years since, the United States has been a country dominated by consumerism (i.e., a country where its society portrays the average person as a consumer of artifacts rather than a producer). After years of this enduring mentality, a new movement has risen to bring people back to their making roots. In 2005, the founder of Maker Media Inc., launched Make: magazine, a quarterly publication that showcases different artifacts that people have made, often giving step-by-step instructions for the reader to replicate the projects (Dougherty, 2012). In 2006, Maker Media Inc. held the world’s first Maker Faire in the San Francisco Bay Area as a way for
makers to meet each other and share ideas. The official Maker Faire website described a Maker Faire:

The Greatest Show (and Tell) on Earth—a family-friendly festival of invention, creativity and resourcefulness, and a celebration of the Maker movement.

Part science fair, part county fair, and part something entirely new, Maker Faire is an all-ages gathering of tech enthusiasts, crafters, educators, tinkerers, hobbyists, engineers, science clubs, authors, artists, students, and commercial exhibitors. (Maker Faire, 2013)

Fueled by factors like the development of online do-it-yourself communities, the expiration of patents on 3D printing (Hornick & Roland, 2013; Krassenstein, 2014), and the rise of the MAKE brand, the Maker Movement has grown tremendously in the past decade. Since the first Faire, the number of Maker Faires held each year has increased. In 2016, over 300 Maker Faires were held world-wide (Maker Faire, 2016). In 2014, there was even a White House Maker Faire in which President Obama gave an address that reinforced the need to return to making by pointing out the following:

Our parents and our grandparents created the world’s largest economy and strongest middle class not by buying stuff, but by building stuff -- by making stuff, by tinkering and inventing and building; by making and selling things first in a growing national market and then in an international market -- stuff “Made in America.” (Office of the Press Secretary, 2014)

In 2012, a non-profit organization known as the Maker Education Initiative was launched with Dale Dougherty as its chairman. The goal of this organization is to “create more opportunities for all young people to develop confidence, creativity, and interest in science, technology, engineering, math, art, and learning as a whole through making” (Maker Ed, 2014). One way that the Maker Education Initiative works toward this goal is by providing resources to help communities create their own makerspace, a place where people can come together and engage in making. A more detailed description of what a makerspace is, is presented in the following chapter.
1.2.2 The Navajo Nation

There is a severe underrepresentation of Native Americans in the engineering field. In the 2010 Census, approximately 0.9% of the total United States population identified as being American Indian and Alaska Native alone (Norris, Vines, & Hoeffel, 2012). Proportionately, one would expect a similar percentage of Native students to be receiving engineering bachelor’s degrees. However, between 2002 and 2010, Native students accounted for only 0.5% of these degrees (Yoder, 2015). This lack of representation becomes even more severe in the engineering workforce. A study by the National Science Foundation (2017) estimated that in 2015, there were over 1.7 million engineers working in engineering occupations in the United States. In this same study, it was estimated that only 4000 of those engineers were American Indian or Alaska Native, just over 0.2% (National Science Foundation, 2017).

There are a number of potential factors that serve as obstacles for Native Americans who seek engineering degrees. Some of the factors that Babco (2005) identified included “insufficient math and science courses, delayed course enrollment, part-time attendance, financial dependence, and having family obligations” (p. 6). Kant, His Horse Is Thunder, Burckhard, and Meyers (2015) conducted a study to understand why more Native Americans from South Dakota were not pursuing careers in engineering. While the results of their study agree with Babco that poverty is a significant factor, Kant et al. determined other obstacles to be a lack of understanding of what engineering is and its relevance to the tribe, the absence of the everyday presence of engineering role models, and the inadequate exposure of engineering from kindergarten to high school (Kant et al., 2015).
The Navajo Nation is the largest of the 566 federally recognized tribes in the United States and is located in the Four Corners region of the American Southwest (National Conference of State Legislatures, 2016). Situated between the Four Sacred Mountains of Sisnaajiní (Mount Blanca), Tsoodzíł (Mount Taylor), Dook’o’oosliíd (San Francisco Peaks), and Dibé Nitsaa (Mount Hesperus) (PBS, 2007; The Decolonial Atlas, 2015) and occupying portions of Arizona, New Mexico, and Utah, it “covers an area approximately the size of West Virginia, and has a population of roughly 200,000 people” (Plank, 1994, p. 6). This is the home of the Diné, a people who are more commonly known to the rest of the world as the Navajo.

There appears to be no consensus regarding the origin of the name *Navajo*. Some claim that it came from the Spaniards and means *clasped knife* while some believe it means *thief* (Haederle, 1992; Sahagun, 1993). Goossen (1995) wrote that the name was derived from the “Tewa word *naabahu: cultivated fields, they took our fields*** (p. 2).¹ What is consistent, however, is that the name *Navajo* is not one that originated from the community itself. Sagahun (1993) reported that “many older Navajos cannot even pronounce the word because the ‘v’ sound does not exist in their language.” Although the federal government of the United States recognizes these people as the Navajo Nation (Indian Affairs Bureau, 2017), members of the community often refer to themselves as *T’áá Diné*, which means *The People* (Goossen, 1995).

When I first began working on this project, I would often default to the name *Navajo*, for this is how the community is commonly referred to by the outside world,

¹ All quotes in this document with text in italics or boldface were formatted identically in the original source material and were not added to provide additional emphasis. Also, throughout this document, brackets are used to denote any material inserted into the original quote.
explaining my usage of it in the research questions. As I learned more about the origins of these names and grew as a researcher, I felt that it was more appropriate for this study to use Diné. Diné is the name that these people chose for themselves, and I believe that it is important to recognize their right to determine how they are identified. While both names are used in this document, I showed preference to Diné. Similarly, the term Navajo Nation is used in this document over Navajo Reservation.

The Diné people have been makers for hundreds of years and continue to excel in making as evidenced by how heavily their handcrafted baskets, pottery, rugs, and so on are sought after worldwide. The Navajo Nation’s rich history of makers and designers, as well as their status as the largest Native American community in the country, made them a natural choice for a study that looked to address the issue of the underrepresentation of Native Americans in the engineering field. While there have already been interventions implemented to encourage all students in the United States to become more interested in science, technology, engineering, and mathematics (STEM), many of these programs come from a Western perspective that may not resonate with the unique learning styles of Native American students such as those from the Navajo Nation (Swisher, 1990).

One example of a divergence between Diné and Western learning styles concerns the role of competition in education. Although group learning in Western education has been recently receiving more attention in both research and practice, the Western culture still tends to use competition among individuals as a motivation for learning. In contrast, Diné students typically prefer to cooperate among their peers rather than competing against them (Case, 1971). The traditional Western educational
institutions present on the Navajo Nation also emphasize the verbal communication of information (Ramasamy, 1996). Conversely, “the Navajo child displays above average visual discrimination and fine motor coordination as well as excellent spatial configuration” (Cattey, 1980, p. 26) and is perhaps better suited to learning through visual and tactile means. Additionally, the Diné people tend to have a more holistic view of the world (Ramasamy, 1996). According to Ramasamy (1996), “Navajos have exceptional abilities to perceive wholeness of a task or object and to be aware of how various parts fit into that wholeness, as is obvious in their work in art, crafts, and sports (Rhodes, 1988a)” (p. 145). If any program is going to be successful at increasing Native American participation in the engineering field, it must not only recognize the cultural differences of Native American communities, but it must also frame them as strengths that can help the engineering field.

1.3 Problem Statement

The Navajo Nation represents the largest Native American community in the United States, both in terms of geographical size and population. Leveraging the community’s strength in making, this study looked to generate several designs for a culturally-contextualized makerspace, one that integrated the unique ways a community understood the experience of making into a design that was both responsive and respectful to the distinctive needs and worldviews of the community that it represented and served. This kind of makerspace has the potential to leverage the Diné’s inherent skills in making to promote engineering skills and attitudes on the Navajo Nation in a culturally appropriate manner. This project provides two significant benefits. First, the knowledge that members of the Navajo Nation gain in a makerspace could be used to benefit the community. For example, a newfound understanding of electricity and
alternative energy learned in a makerspace could inspire a Diné maker to harness wind energy to power his or her home. Another entrepreneurial Diné maker could use the makerspace as an incubator for a startup company, helping to create jobs in the community.

The second significant benefit is that learning about engineering through making may cause members of the community to consider pursuing a career in engineering. Doing so will help provide a benefit to the engineering field at large. Native Americans, such as the Diné, have a unique and valuable perspective. Not adequately incorporating their unique perspective into the engineering field threatens the diversity of ideas that is required to solve the world’s toughest problems (Foster & Jordan, 2014; Meadows et al., 2015). Currently, there are no known examples of how a culturally-contextualized makerspace can be designed to promote interest in and exposure to engineering careers for a Native American community. The purpose of this study is to develop the design of a culturally-contextualized makerspace for the Navajo Nation. The following research questions guided the study:

1. In what ways do the Navajo already exhibit maker qualities?
2. How can Navajo and Maker culture be integrated in order to design a culturally-contextualized makerspace?
CHAPTER 2
LITERATURE REVIEW

A literature review was conducted on the relevant topics for this dissertation. The review was initialized by using scholarly search engines such as Google Scholar and by searching through the databases of professional organizations like the American Society for Engineering Education. After the initial review, additional texts were obtained by searching through the references from the first batch of articles. This process was then repeated until saturation was attained (i.e., the same authors and texts repeatedly kept appearing and no new sources of information were obtained).

2.1 Native American Engineering Education

A body of research has investigated why minorities like Native Americans are underrepresented in the engineering field. Shehab, Walden, and Wellborn (2015) conducted a qualitative study that measured the level of influence certain factors had on minority students in pursuing a career in engineering. Their study found that Native Americans are most motivated by interest in engineering and least motivated by social recognition factors such as prestige (Shehab et al., 2015). Shehab et al. suggested that one way to increase interest in pursuing an engineering career is to simply make students aware of all of the types of problems that engineers can solve.

Meadows et al. (2015) investigated how to improve the experience of marginalized students on engineering design teams by trying to understand the different implicit and explicit ways students may be marginalized. For example, Meadows et al. found that the lack of Native American role models in the STEM fields may be demotivating for many Native students. They also mentioned that Native American
students typically perform better when they can see the cultural relevance of an assigned project.

Ellingsen, Degen, Bedillion, and Muci-Kuchler (2014) came up with an intervention to increase interest in STEM careers for Native students in North and South Dakota. The program involved a mix of lectures and hands-on learning experiences where the students learned about concepts like buoyancy, controls, and pressure. These concepts were then applied to the design and construction of a remote-controlled submarine. One of the biggest weaknesses of this program was that there was no mention if the different cultures or worldviews of the students were considered in the development of the intervention.

In contrast to Ellingsen et al. (2014), Bang and Medin (2010) developed a culturally relevant science curriculum for an urban intertribal Native American community and that of the Menominee Reservation. Using the participatory action research (PAR) methodology, Bang and Medin worked directly with community researchers in all phases of the research process. They made sure that the community members were able to add their valuable and unique worldviews into the development and administering of the curriculum. As a result, the activities they developed framed science as a practice that the community has been doing for hundreds of years, rather than as a foreign act, which allowed the students to see the relevance of science in their own lives (Bang & Medin, 2010).

There are a number of projects that are focused on increasing the number of Native American students who pursue careers in engineering. The Pre-Engineering Education Collaborative features a partnership with one 4-year institution, North Dakota
State University, and four autonomous tribal colleges: Cankdeska Cikana Community College, Turtle Mountain Community College, Fort Berthold Community College, and Sitting Bull College (Pieri et al., 2015a). The program is designed to help the tribal colleges develop a 2-year pre-engineering program that prepares Native American students to transfer to North Dakota State University (Pieri et al., 2015b). To make the transition from the tribal college to the 4-year institution as smooth as possible, Padmanabhan, De Saram, Schanandore, Schanandore, and Pieri (2013) described how the students were offered a 2-week summer program in which they received a full semester construction surveying course. The program offered a number of layers of support for the students—all of the teaching assistants were Native American and readily available both for academic support and addressing the students’ anxieties or fears about attending a 4-year school (Padmanabhan et al., 2013).

The Alaska Native Science and Engineering Program (ANSEP) is another program that involves efforts to increase interest in STEM careers among Native Americans (Yatchmeneff, 2015). ANSEP (2015) is “a longitudinal education model that provides a continuous string of components beginning with students in sixth grade and continuing on through high school, into science and engineering undergraduate and graduate degree programs through to the PhD.” In addition to providing advanced mathematics and science courses, ANSEP also offers other STEM opportunities like a computer build workshop and a summer bridge program that helps recently graduated high school students make the transition to college (Schroeder & Lazzell, 2013).

The American Indian Research and Education Initiative (AIREI) pairs a tribal college or university with a mainstream institution “to fund student and faculty research
teams to bring energy projects to tribal land” (Energy.gov, 2012). One of the three pairs of schools funded by AIREI included researchers from Navajo Technical University (NTU) and Arizona State University to investigate whether solar energy is a viable solution for providing electricity to the Navajo Nation (Energy.gov, 2012).

To help promote engineering education on the Navajo Nation specifically, Foster and Jordan (2014) investigated how the philosophy of learning in engineering aligns with the Diné philosophy of learning. The researchers found that there was congruency in the types of problems the two philosophies address, their problem-solving methods, their understandings of reality and learning, and the values they uphold. However, there were also a number of potential deviations between the two such as the purpose of learning, what solutions look like, how decisions are made, and understandings of knowledge, identity, and education.

Also, on the Navajo Nation, Samsung (2015) and the National Environmental Education Foundation awarded an outdoor STEM lab to Nizhoni Elementary School. The lab is “designed to work in any climate for a hands-on, immersive environmental education experience which consists of a Growing Dome greenhouse where students can apply the scientific method to cultivation projects” (Samsung, 2015). To help get their students become more interested in learning about STEM careers, some schools on the Navajo Nation have started a robotics club or team (Pineo, 2016; Quintero, 2017; Silversmith, 2014). Additionally, Arizona State University hosted a STEAM (science, technology, engineering, art, mathematics) camp where students from the Navajo Nation built Rube Goldberg machines to learn about physics, math, and engineering design (Keane, 2014; Toscano, 2014).
While these initiatives on the Navajo Nation are encouraging, they all suffer the same flaw; all of them feature activities that may not be relevant to the Diné community. To help address this issue, some of these programs have tried to make their content culturally relevant. For example, the Rube Goldberg machines that the students designed had to tell a culturally relevant story (Meadows et al., 2015). Additionally, one of the robotics teams won an award for the idea of making an app to help people learn the Diné language (Silversmith, 2014). I feel that these efforts are superficial in nature and that they do not change the fact that robotics, apps, and Rube Goldberg machines may not be the most appropriate way to encourage STEM education on the Navajo Nation. That is not to say that I believe that these programs are harmful for the community. I have started a number of robotics teams on the Navajo Nation and, in general, I have received much support and appreciation from the community. However, I also believe that interventions to promote STEM education that are designed, implemented, and evaluated from outside the community will always be limited in the scope of their impact. They will never fully resonate with the community.

From a critical perspective, one could argue that a culturally-contextualized makerspace designed by someone outside of the community is inherently flawed and will also fail to resonate with the community. It should be emphasized that I did not look to design a makerspace for the community. Rather, my aim was to synthesize the ideas and needs expressed by the community members to form several preliminary designs. My hope is that the community will continue to refine these designs and then take on the responsibility of implementing and evaluating them.
Another valid point of criticism is the argument that regardless of who designs the makerspace, the concept itself is just as foreign to the Diné as the other mentioned interventions. Though true, unlike robotics or Rube Goldberg machines, making is an activity that the Diné have been doing for hundreds of years. Additionally, I did not seek to transplant a Western makerspace onto the Navajo Nation, nor was I interested in taking a Western makerspace and superficially modifying it to give it a Diné “spin.” In this study, I used feedback from the community to directly inform all aspects of the design of the makerspace, including what is made inside of it, where it is located, and how making is performed. I believe that the results of this project not only challenge the traditional Western perspectives of making and makerspaces, but it will also provide the Navajo Nation with a resource that they can use to promote interest in engineering careers in a culturally relevant way that is meaningful to the Diné people.

2.2 What is Making?

There has been a great deal of attention devoted to the educational merits of making. Within the context of education, making is rooted in the educational philosophies of John Dewey, Maria Montessori, Friedrich Froebel, and Seymour Papert (Vossoughi & Bevan, 2014). As Ansbacher (1998) explained, one of the tenets of Dewey’s experiential learning philosophy is that genuine knowledge is generated when people are given experiences that present new problems. These problems should be appropriate for the age and skill level of the individual and should inspire the individual to generate knowledge from within (Ansbacher, 1998). Montessori’s educational philosophy emphasizes learning through discovery by interacting with materials and using the senses (Montessori, 2013). Froebel, best known for inventing and developing the concept of kindergarten, advocated for learning through structured playing (Tarr,
Similarly, Papert and Harel (1991) promoted “learning-by-making” (p. 6). For Papert (n.d.), “this is how real learning happens. You understand just enough to get going, to do something and to learn by doing and by discovery.”

In addition to being hands-on, learning through making is often a collaborative activity. One of the ways that makers collaborate is by working together in what is referred to as a *makerspace*. Kelly (2013) described makerspaces as “community-oriented spaces where people gather to create, make, and learn using a variety of tools” (p. 1). Foster, Wigner, Lande, and Jordan (2015) noted the social nature of making as they acknowledged that many makers work in makerspaces “to benefit from opportunities to continue [to] learn from, teach and mentor other Makers” (pp. 3-4).

Makers do not even need to meet each other to collaborate in a makerspace. At the Makeshop within the Children’s Museum of Pittsburgh, participants may come in and work on a project for a while and then leave their unfinished artifact for another maker to finish (Sheridan et al., 2014). Even though the makers never meet each other, their collaboration promotes the sharing of ideas as new makers become inspired through the visual inspection of the unfinished artifacts.

The range of activities that the making community might classify as making is extensive, but not limitless. Vossoughi and Bevan (2014) found in their literature review on making and tinkering the presence of a consensus “that making is a broad category of activity that involves people ideating, designing, and producing physical or virtual object[s] in the world (Blikstein, 2013)” (p. 10). Defining making in this way automatically eliminates more abstract forms of making, which were a critical finding of this project.
I have also found that there appears to be a bias towards forms of making that utilize modern manufacturing processes or materials over more traditional forms of making. For example, McGrath (2016) designed a general access makerspace for UC Berkeley, which included equipment such as “3D printers, vinyl cutters, and kits for experimenting with electronics and coding such as Arduino and Raspberry Pi, as well as tools for work in textiles, including wearable technology” (p. 97). Of the mentioned pieces of equipment, only the textile tools could be considered a traditional form of making, and even then, they appeared to only be included as a means to facilitate the ability to make wearable technology. A similar trend can also be found in the forms of making that Make: magazine promotes. For instance, Buechley (2014) investigated the types of projects that were featured on the covers of 39 issues of the magazine and found that over half of the covers featured projects involving electronics, nearly a third featured vehicles, and over a quarter highlighted projects related to robotics. Maker Faires have only reinforced this bias by selecting a bright red robot as their mascot.

While I did not encounter much literature that specifically addressed the unique ways that the Diné people understand the making experience, I did find that some artists from the Navajo Nation purposefully include imperfections in their work (Benally, 1994). Benally (1994) explained the role of intentional imperfections for Diné artists:

Any object that they make is stamped with humility. A silver jewelry design may be intentionally stamped crookedly, or a break may be woven into the border of a rug, so the artist may not be cornered or trapped in his or her own design. The crooked stamp or uneven line is a statement of humility,
growth, and spiritual freedom to participate in Hózhógo iiná (the good life). (p. 27)

Culturally motivated differences in making, like this one, were an important piece of what I sought to discover. By understanding the unique Diné motivations for making, it is possible to develop more effective programs and curricula to increase interest in engineering careers for the students of the Navajo Nation.

2.3 Makerspaces

2.3.1 What is a Makerspace?

It is important for this document to answer the question: What is a makerspace? Unfortunately, while reviewing the literature, it was apparent that this question was a difficult one to answer due to the wide variety of meanings that people have associated with the term. Even the term makerspace itself is not universally accepted as other terms like hackerspace, fab lab, media lab, and STEAMspace have been used interchangeably to describe the same phenomenon (Meehan, Gravel, & Shapiro, 2014). Bowler (2014) described a makerspace in the following way:

A physical place in the library where informal, collaborative learning can happen through hands-on creation, using any combination of technology, industrial arts, and fine arts that is not readily available for home use. The underlying goal of a makerspace is to encourage innovation and creativity through the use of technology—to offer a place where everything from STEM learning to critical expression to future start-ups can be nurtured. (p. 59)

Another interpretation of makerspaces that I encountered was “areas for makers to connect and share thoughts, ideas, questions and projects around specific topics of interest” (MakerSpace, n.d.). These definitions provide only a sample of the different meanings that people have assigned to the term makerspace. Despite their differences,
common characteristics have emerged throughout the literature, which are discussed in the next section.

2.3.2 Characteristics of a Makerspace

While there is much variety in makerspaces, common characteristics have emerged throughout the literature. The first shared aspect of makerspaces determined in the literature review was that makerspaces are physical spaces, though the location seems to be irrelevant. Makerspaces are found in schools (Balonon-Rosen, 2015), museums (Oates, 2015), libraries (Bowler, 2014), church basements (Sheridan et al., 2014), and even hospitals (Nelson, 2015). Makerspaces are more than just physical places, they are also communities. People go to makerspaces to collaborate on projects, learn from each other, and to socialize (Ames et al., 2014; Liberating Ourselves Locally, 2012; Sheridan et al., 2014). MIT took the community aspect of makerspaces a step further by creating a network of makerspaces known as a *makersystem* (MIT Project Manus, 2017).

While many of the makerspaces described in the literature were physical places, there were several noteworthy exceptions. Nelson (2015) reported that a PhD student sought “to solve the problem of teaching science and math skills to kids inside hospitals” by developing a makerspace for a children’s hospital. The only problem was that many of the patients were not able to leave their rooms, which was solved when the student developed a mobile makerspace. Instead of a physical room, “the space is a metal cart filled with the equipment and materials you would need for small-scale engineering projects” (Nelson, 2015). Another example of a mobile makerspace, one that operates in the Gainesville, Florida area, is Wizzbangz (2016), “a mobile classroom and maker/hacker space that offers project based STEAM classes where students build
robots and a multitude of other projects.” Last, Moorefield-Lang (2015) discussed six case studies of mobile makerspaces.

Makerspaces often value the process of making over the end artifact. As a result, Gutwill, Hido, and Sindorf (2015) used the term *tinkering* as opposed to *making*. It was also determined in the literature that makerspaces are holistic and interdisciplinary. They bring together disciplines that are not normally thought of as being related, such as sewing and electronics, and they create new and exciting possibilities such as wearable electronics (Oates, 2015; Sheridan et al., 2014). The use of modern materials in makerspaces, such as computers and sensors, alongside traditional making materials, such as wood and cardboard, bridges the gap between low tech and high tech and creates a new arena for making, *middle tech* (Eisenberg & (Nishioka) Eisenberg, 1998; Gutwill et al., 2015). This combination of new and old materials and technologies being drawn from many different disciplines creates exciting possibilities.

Learning in makerspaces occurs in three common ways. First, makers learn from facilitators or staff that have been hired specifically to help people learn how to use the space’s equipment (Buhler, Gonzalez, Bennett, & Winick, 2015). Second, makers learn from interacting with fellow makers by asking questions, observing the work of others, and collaborating on projects (Petrich, Wilkinson, & Bevan, 2013). Petrich et al. (2013) described how their makerspace limits the supply of space, tools, and materials in the hope that by promoting the sharing of physical resources, makers would be encouraged to talk to each other and share ideas. Collaboration comes in the forms of multiple people working on the same project simultaneously or people working separately on artifacts designed to interact with each other (Gutwill et al., 2015). In the third way,
makers learn by themselves through the playful exploration of the materials available in the space (Vossoughi, Escudé, Kong, & Hooper, 2013).

When makerspaces encourage students to work on projects that are meaningful to them, making becomes a source of empowerment (Martinez, 2015). Many makerspaces allow makers to choose the types of things they make, giving them authorship of their work. Making is also empowering because it promotes anti-consumerism (Kuznetsov & Paulos, 2010). Makers are encouraged to meet their needs through making, repairing, and repurposing rather than consuming (Sivek, 2011).

2.3.3 Common Categories of Makerspaces

In their literature review on making, Vossoughi and Bevan (2014) categorized makerspaces into three different types. The first category they defined was *entrepreneurship & community creativity*. Makerspaces in this category offer space and equipment that are available to the public for a membership fee. Often, these spaces serve as incubators for entrepreneurs by allowing them to produce aesthetically pleasing and functional prototypes for new products. The Skillhouse in Gainesville, Florida is one example of this type of makerspace (Skillhouse, n.d.). The second category that Vossoughi and Bevan (2014) mentioned, *STEM pipeline and workforce development*, focuses on activities that encourage high school and undergraduate students to develop STEM interests and skills through design projects. These types of spaces may also be interested in diversifying and increasing the number of students in the STEM pipeline. The University of Florida's Machine Intelligence Lab is an example of this category.

The third category mentioned by Vossoughi and Bevan (2014), *inquiry-based education*, is geared towards younger makers. The design of these spaces emphasizes
the learning that occurs during the process of making, not on the final artifact itself.
Museum-based makerspaces such as the Makeshop in the Pittsburgh Children’s
Museum fall into this category (Sheridan et al., 2014). Additionally, I believe that there is
another type of makerspace that was not considered by Vossoughi and Bevan. The Mt.
Elliot Makerspace described by Sheridan et al. (2014) leads me to define a fourth
category, community-centered. Community-centered makerspaces are specifically
designed to serve the needs of the communities in which they operate. It is important to
note that this list is not exhaustive and that there are even more makerspaces that do
not neatly fit into any of these categories. Some spaces may be hybrids that overlap in a
number of these categories, while some spaces belong to a category of their own.

2.4 Inclusivity of the Maker Movement

Makerspaces have much diversity in terms of what they look like, where they are
located, and how they are sustained. Unfortunately, this diversity does not seem to
extend itself to the making community. The front page of Make: magazine's website
proclaims, “We are all Makers” (Make:, 2015a). However, the magazine’s 2014
audience demographics tell a very different story (Make:, 2014). The vast majority of the
readers of Make: magazine are older, affluent, and formally educated men that hardly
represent the universal population that the magazine has come to represent (Brahms,
2014; Make:, 2014). Similar demographic trends can be found in a survey that sampled
attendees of the 2014 San Mateo Maker Faire (Maker Media, 2014), in addition to an
analysis on the diversity of people who work at Make: magazine and the individuals who
appear on the magazine’s covers (Buechley, 2014). Make: magazine’s official website
claims to be “the leading voice of the maker movement” (Make:, 2015b). However,
Buechley (2014) was critical about how effectively Make: can lead a movement that
promotes the democratization of making if their staff and consumer base are not representative of the rich diversity they claim to represent.

Promoting culturally responsive teaching (CRT) within the context of making is one way for the Maker Movement to broaden participation. Gay (2010) defined CRT “as using the cultural knowledge, prior experiences, frames of reference, and performance styles of ethnically diverse students to make learning encounters more relevant to and effective for them. It teaches to and through the strengths of these students” (p. 31). CRT is validating, empowering, transformative, and emancipatory (Gay, 2010). Vossoughi et al. (2013) agreed that equity is more than just providing access to opportunities to marginalized people. To them it requires “integrating students’ cultural and intellectual histories” (p. 1). By promoting making activities that not only accept the culture of the community, but embrace it as a source of strength, the Maker Movement can reach a more diverse population.

Another way for the Maker Movement to be more inclusive is in how makerspaces are designed. Meehan et al. (2014) developed a card sorting task that allows communities to design a makerspace that aligns with their needs and values. Riley, McNair, and Masters (2017) used ethnographic methods and critical discourse analysis to determine the practices of six makerspaces that actively promote diverse participation. They found that these makerspaces have practices that openly welcome diversity in the types of projects that are supported as well as in gender identity, sexual orientation, ability, race, and ethnicity (Riley et al., 2017). Morocz et al. (2016) found that to promote higher participation in a university makerspace, efforts should be made to reduce student anxiety over engaging in design activities. Additionally, Martinez
(2015) described five areas in which makerspaces can be made more inclusive. First, Martinez explained that students should be empowered by having them make things that are relevant to them. Second, the making community should be culturally responsive and situated by viewing cultural practices in a maker light. Third, the makerspace environment needs to be designed in a way that everyone feels comfortable making there. Fourth, competition should be reduced, for it may cause making to be intimidating to some. Fifth, the making community should embrace and praise all kinds of making.

Community-centered makerspaces also have the potential to address the lack of inclusivity in the Maker Movement. A program known as Happy Feet was started by FabLab Nairobi (Goehrke, 2014). In this program, Kenyans of all ages are taught how to design and build 3D printed shoes which can help prevent foot deformities caused by tiny fleas that plague their poorer communities (Goehrke, 2014; Martinez, 2015). Liberating Ourselves Locally (LOL) is another community-centered makerspace (Musings of a Renegade Futurist, 2014). As reported by Meier (2015), LOL is “a local movement whose primary purpose is to serve our communities: people of color, immigrants, poor folks, women, youth, transfolks and queers in and around the Bay Area.” Where LOL differs significantly from Make: magazine is that their leadership is representative of the diverse population that uses the makerspace (Meier, 2015). For more examples of community-centered makerspaces, see Riley et al. (2017).

At some level, it appears that the making community has recognized its lack of inclusivity and has begun the work on correcting it. For example, the Maker Education Initiative partnered up with Cognizant to offer the Making the Future Grant for after
school and summer programs focused on making. They are interested in serving the following demographic:

Children of all backgrounds in K-12 grade levels. There are no specific requirements for socio-economic, gender, or race of targeted children, although our goal is to have at least half of the funded programs to be serving high-need communities, and encourage focusing on girls and minorities, both under-represented in the STEM disciplines. (Cognizant, 2013)

While this initiative is promising, it does not change the fact that the Maker Movement has not lived up to its promise of democratizing making, which is a detriment. So many communities like the Navajo Nation could benefit from more making opportunities. Not adequately incorporating these communities and populations into the Maker Movement is also a disservice to the larger making community. For example, in the process of conducting this study, I found a number of unique ways in which the Diné understand the experience of making. Many of these unique understandings have the potential to benefit all makers. Sivek (2011) described how Make: magazine used language that encouraged readers to reach their full potential or self-actualization through the act of making. In the same way, I encourage the leaders of the Maker Movement to help the movement reach its own potential or self-actualization by working towards broadening participation.

2.5 Maslow’s Theory of Human Motivation

Maslow (1943) described human motivation as being driven by a desire to meet various needs. Maslow noted that these needs appeared to form a logically ordered hierarchy ranging from lower-level needs, such as the need for food, to higher-level needs, like the need to learn and grow as an individual. Often this hierarchy is depicted as a pyramid: the lower-level needs form the foundation while the higher-level needs
ascend toward its pinnacle. The imagery of a pyramid reinforces the hierarchical nature of the framework (i.e., if people are lacking in lower-level needs, they will not be motivated to pursue the satisfaction of higher-level needs until the lower-level ones are satisfied; Maslow, 1943). For example, someone who is starving will be singularly consumed with the purpose of finding food rather than higher-level needs like receiving praise from peers. As Maslow (1943) wrote,

> The urge to write poetry, the desire to acquire an automobile, the interest in American history, the desire for a new pair of shoes are, in the extreme case, forgotten or become of secondary importance. For the man who is extremely and dangerously hungry, no other interests exist but food. (pp. 373-374)

The human need for food is so powerful that Maslow (1943) placed it alongside other physiological needs as the first category in his hierarchy. These physiological needs are extremely primitive and include the requirement for food, water, oxygen, sleep, and shelter. Maslow’s next level is the natural human desire for safety. Safety needs can manifest themselves into different forms, ranging from a person’s desire for physical safety to the desire for financial security. Beyond physiological and safety needs are ones concerning love. Love needs are met by fostering affectionate relationships with others. Once the human need for love has been met, individuals will begin to focus on addressing their need for esteem. This level of the hierarchy addresses a person’s need for self-esteem as well as receiving esteem from others in the form of praise and appreciation.

Having satisfied these first four needs, people may shift their attention towards self-actualization, which Maslow (1943) defined “as the desire to become more and more what one is, to become everything that one is capable of becoming” (p. 382). Perhaps self-actualization is best described by the United States Army’s slogan at the
end of the 20th century: “Be all you can be.” It concerns the need that people have for reaching their full potential. While this need may manifest itself in different ways depending on the person, medical students studying to become the best doctor that they can be is an example of one act that may be motivated by the need for self-actualization.

While Maslow’s original hierarchy only included five categories of needs, later in his life he added a sixth category known as transcendence (Koltko-Rivera, 2006). According to Koltko-Rivera (2006), people who are motivated by transcendent needs “come to identify with something greater than the purely individual self, often engaging in service to others” (p. 306). In other words, once individuals have successfully satisfied their own personal needs, they may begin to look beyond themselves by helping to meet the needs of others. A summary of Maslow’s six categories of needs can be found in Table 2-1.

<table>
<thead>
<tr>
<th>Category of Need</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physiological</td>
<td>food, water</td>
</tr>
<tr>
<td>Safety</td>
<td>physical safety, financial security</td>
</tr>
<tr>
<td>Love</td>
<td>affectionate relationships with other people</td>
</tr>
<tr>
<td>Esteem</td>
<td>self-respect, appreciation, prestige</td>
</tr>
<tr>
<td>Self-actualization</td>
<td>achieving one’s full potential (athletically, academically, artistically, etc.)</td>
</tr>
<tr>
<td>Transcendence</td>
<td>looking beyond the needs of oneself and helping others</td>
</tr>
</tbody>
</table>


Examples of some of these categories of needs are present in the making literature, especially in Make: magazine. Sivek (2011) conducted a textual analysis study on eight issues of Make: and found that the magazines promised self-actualization to its readers by suggesting that they “will find personal gratification and a sense of accomplishment through participation in ‘making,’ or the completion of creative
and usually technology-focused projects like those in the magazine” (p. 189). Sivek also found that readers of the magazine were encouraged to look beyond themselves towards what might be referred to as a state of transcendence:

Though the text and Faire call the individual maker to action through innovative projects that reflect their self-determination, the individual is also constructed as a unique and significant part of a larger effort to improve the body of shared knowledge available to all makers, and to use that knowledge for the betterment of (American) society, as have generations of makers before them. (p. 202)

Outside of the making literature, Maslow’s framework has been used in a variety of disciplines including education (Milheim, 2012), management (Benson & Dundis, 2003), and health care (Jackson et al., 2014). However, it should be noted that despite its popularity, Maslow’s framework has not escaped criticism (Neher, 1991). For example, Mathes (1981) proposed a revision of the framework that reduces the hierarchy to just three separate categories of needs: physiological, belongingness, and self-actualization. Even if one accepts the conclusions of Maslow at face value, concerns still exist with describing the experiences of a specific community with an externally derived framework. Maslow (1943) described the generalizability of his theory in the following way:

Certainly, in any particular culture an individual’s conscious motivational content will usually be extremely different from the conscious motivational content of an individual in another society. However, it is the common experience of anthropologists that people, even in different societies, are much more alike than we would think from our first contact with them, and that as we know them better we seem to find more and more of this commonness. We then recognize the most startling differences to be superficial rather than basic, e.g., differences in style of hair-dress, clothes, tastes in food, etc. Our classification of basic needs is in part an attempt to account for this unity behind the apparent diversity from culture to culture. No claim is made that it is ultimate or universal for all cultures. The claim is made only that it is relatively more ultimate, more universal, more basic, than the superficial conscious desires from culture to culture, and makes a somewhat closer approach to common-human
characteristics. Basic needs are *more* common-human than superficial desires or behaviors. (pp. 389-390)

Red Horse (1997) illuminated just how universal these basic needs are by providing a glimpse of how a group of Diné elders felt about Maslow’s framework. After presenting the framework to the elders, Red Horse found,

They were also impressed with Maslow but somewhat confounded by the direction of priorities in his hierarchy of needs. They noted that, in Navajo terms, his thinking was backwards. They did not downplay the importance of basic human needs such as food, clothing, and shelter, but indicated that the Navajo belief system would turn Maslow’s triangle upside down. Essentially, the elders ranked self-actualization as the most important theme in human development because they attributed a spiritual context to self-actualization. In their belief, spirituality is the sine qua non to life; it guides all other important needs in human development. (p. 247)

Red Horse (1997) observed two interesting concerns that the elders had for Maslow’s hierarchy. First, they questioned the order in which the needs in the hierarchy were arranged. By making the physiological needs category the foundation of the pyramid, the elders believed that Maslow implied it was the most important category, which conflicted with their belief that the higher-level needs are the most significant needs. Second, the elders stressed the importance of spirituality, a concept not directly addressed by Maslow’s framework.

It is important to note that while Maslow’s theory of human motivation is well-known in the field of psychology, it is not an absolute framework for perfectly characterizing human motivation. Human motivation is an extremely complex phenomenon, and it seems impossible to describe it accurately in such a simplified way. Maslow (1943) himself noted a number of cases that appeared to defy the hierarchy as he defined it, providing the following example:

There are other, apparently innately creative people in whom the drive to creativeness seems to be more important than any other counter-
determinant. Their creativeness might appear not as self-actualization released by basic satisfaction, but in spite of lack of basic satisfaction. (p. 386)

Discrepancies in the hierarchy are found in the literature as well. Wahba and Bridwell (1976) conducted a review on a number of studies testing Maslow's hierarchy and found that "there is no clear evidence that human needs are classified in five distinct categories, or that these categories are structured in a special hierarchy" (p. 224). Despite the theory's shortcomings, it was chosen as the theoretical framework in this study for reasons explained in Section 3.7.

2.6 Review of the Engineering Design Process

For over half a century, a wealth of research has been conducted in the broad field of engineering design (Evbuomwan, Sivaloganathan, & Jebb, 1996). The goal of this section was not to summarize this massive body of research, but rather to highlight specific areas of the engineering design process relevant to this study.

The engineering design process was defined in the literature in a variety of ways. Hubka and Eder (1987) defined engineering design as “a process performed by humans aided by technical means through which information in the form of requirements is converted into information in the form of descriptions of technical systems, such that this technical system meets the requirements of mankind” (p. 124). Similarly, Dym, Agogino, Eris, Frey, and Leifer (2005) defined engineering design as “a systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients’ objectives or users’ needs while satisfying a specified set of constraints” (p. 104). As a final example, the Accreditation Board for Engineering and Technology defined the engineering design process as follows:
The process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic science and mathematics and engineering sciences are applied to convert resources optimally to meet a stated objective. Among the fundamental elements of the design process are the establishment of objectives and criteria, synthesis, analysis, construction, testing, and evaluation. (Ugural, 2015, p. 5)

While there are many similarities among the various ways in which the engineering design process has been described, there is no set standard in how the steps for this process are defined. For this study, I chose to use the steps defined by Shigley and Mischke (2001): recognition of need, definition of problem, synthesis, analysis and optimization, evaluation, and presentation.
CHAPTER 3
FIRST RESEARCH QUESTION METHODOLOGY

This chapter investigates the research design that was implemented to address
the first research question. It begins with an overview of qualitative research: what it
entails and why it was appropriate for this study. Next, I provide a discussion and
justification for each of the selected qualitative research design elements as defined by
Crotty: epistemology, theoretical perspective, methodology, and methods. I then
address the concept of quality in the context of this project. Finally, this chapter
concludes with a brief summary.

3.1 Qualitative Research Overview

Qualitative research differs in many ways from the quantitative research that is
commonly found in the engineering field. Engineering researchers measure easily
quantifiable phenomena such as engine speed, load on a structure, current being drawn
from a circuit, and the number of clock cycles it takes for an algorithm to run. They
collect this data to learn how to improve their designs or to predict how they will perform
in the field. However, when an engineer wants to measure an abstract phenomenon
such as how well a student has learned how to apply the engineering design process, it
becomes clear that quantitative research methods may not be appropriate, which is
where qualitative research methods can help.

While quantitative research is best suited to objectively study the relationships
among variables in a sample and to use the information to make inferences about a
larger population, qualitative research aims to understand the meaning people assign to
their experiences (Creswell, 2013). Typically, this meaning is an abstract and
unquantifiable phenomenon. The data that describe this meaning can take many forms,
including quotations from interviews, images, physical artifacts, and sound recordings (Bernard & Ryan, 2009). After the data have been analyzed, rich descriptions are used to communicate the findings.

In qualitative research, the researcher is the primary instrument in collecting and analyzing data (Merriam, 2009), which may make researchers with a quantitative orientation a bit uncomfortable. They would argue that this opens the door to subjectivity. Two researchers could collect and analyze the same data and arrive at two different results. While this is true, it should be noted that subjectivity and differences in measurement instrumentation are not solely issues in qualitative research. Consider Robert Hooke studying a cell with his first microscope. His observations and understanding of them would probably differ drastically from those of a modern biology researcher using a state of the art microscope to study the same cell.

Just as quantitative researchers have methods to mitigate these issues, qualitative researchers have their own methods. One such method, bracketing, is where the researcher identifies all their potential biases that might influence how they collect and interpret the data (Dwyer & Buckle, 2009). Becoming aware of those biases helps the researcher to try to set them aside to minimize their effect on the research. Another method is triangulation, in which the methods used and the types of data that are collected are diversified to see if they corroborate (Golafshani, 2003; Sheridan et al., 2014). The concept of quality in a qualitative research study is discussed in further detail in Section 3.8.

Qualitative research is an inductive process. Small pieces of data are analyzed to find emergent patterns and build theory (Borrego, Douglas, & Amelink, 2009; Merriam,
Another unique feature of qualitative research is that data collection and analysis occur in parallel, each informing one another (Merriam, 2009), which allows for the research design to be flexible. For example, while qualitative researchers are analyzing the results of their first interview, they may discover that they missed an opportunity to ask important questions. The researchers can then adjust their protocol to make sure that the questions are addressed in future interviews.

Finally, because the goal of qualitative research is not to generalize findings to large populations, a different approach is used for sampling. Rather than using random sampling, qualitative researchers purposefully select participants, choosing individuals who can best offer information that may help to answer the research questions. By providing a rich description of the phenomenon under study, the researcher leaves the reader with the responsibility of interpreting the findings and transferring them to another context. Because one person may elicit a wealth of qualitative data, the requirement for large sample sizes placed on quantitative research does not hold for qualitative research studies (Borrego et al., 2009).

Crotty (1998) described four elements that comprise a qualitative research design: epistemology, theoretical perspective, methodology, and the methods. An additional element, the research question, also plays an important role in the design of the research project. Each of these five elements informs the others. While the research question is often understood as the first choice made in a research design, the reality is that the design process is not linear at all. For example, in a PAR study, the community must be directly involved in the development of the research question. In this case, the methodology, PAR, must be chosen before the research question.
choose to start their research design is not important as long as each of the five elements inform each other and are chosen appropriately. Figure 3-1 depicts the relationship among the five elements in a qualitative research design, with the shaded region representing the goal for all research designers: a study where all of the elements are in harmony with each other.

Figure 3-1. Relationship among the five elements in a qualitative research design

3.2 Epistemology

The first element described by Crotty is the epistemology of the study. An epistemology is the collection of assumptions that one makes regarding the nature of knowledge. In most engineering research, an objectivist epistemology is chosen. Objectivism assumes that knowledge exists throughout the universe, waiting to be
discovered (Crotty, 1998). Objectivists believe that there is only one reality and that it is measurable and observable, which is an appropriate epistemological stance for engineering research questions like, “Does a novel type of engine get better gas mileage on the highway than current designs?” There is only one answer to this question: the engine in question either outperforms current engines or it does not. There is no room left for interpretation. However, objectivism is ill-suited when faced with a research question like, “How do the Navajo describe their experience of working in a makerspace?” What happens when two people describe two very different experiences? Intuition tells us that it is possible for two people to undergo the same experience and have two very different interpretations of it. So instead of choosing objectivism for this research study, a more flexible epistemology was chosen, one that did not demand one Truth, but rather, could handle the possibility of multiple truths.

Constructionism is an alternative epistemological choice to objectivism. In constructionism, knowledge is constructed through the interaction of humans with the rest of the universe. This belief implies that “before there were consciousnesses on earth capable of interpreting the world, the world held no meaning at all” (Crotty, 1998, p. 43), quite different from the objectivist belief that the universe is full of knowledge, regardless of whether anyone is there to interact with it.

A bricoleur is a French word for someone who can construct something new using a wide variety of available resources (Crotty, 1998; Kincheloe & McLaren, 2005). In many ways, a maker represents the modern-day manifestation of the bricoleur. Just as makers find creative new uses for common objects, bricoleurs also see their available resources not for what they are, but for what they have the potential to be
(Levi-Strauss, 1966). For example, a bricoleur might see an old broomstick as a potential lever or a carrying pole. Like the bricoleur, constructionist researchers need to free themselves from the conventional meanings that are associated with objects and see them in a new light, because it is by interacting with the objects in new ways that new knowledge is constructed.

Constructionism is an epistemological choice that is often associated with the Maker Movement (Vossoughi et al., 2013). As individuals engage in making activities, they are constructing both physical artifacts and knowledge. These two parallel processes are not independent, for they both inform each other. Learning allows one to make more sophisticated artifacts, while physically making something facilitates the learning of new concepts. In that sense, makerspaces become special places as the artifacts made there can be viewed as the physical manifestations of the knowledge constructed in making them. Different people could have access to the same supplies and tools in a makerspace, yet they may produce completely different physical artifacts, reflecting that they may also have constructed different knowledge. These variations reinforce the constructionist concept that there is no true interpretation of available resources.

While constructionists deny the existence of an objective truth, they will admit that some truths are more useful than others. Engineers should feel comfortable with this concept because the same is true in engineering design. When engineers are asked to design a device to solve a problem, they may come up with several different designs that meet all of the specifications. However, some of the designs will meet the specifications better than others. In this case, a decision matrix may be used to pick the
design that best meets the needs of the project. It is important to note, however, that the
use of a decision matrix does not rule out the possibility that there is still a better
solution that has not been thought of yet. In the same spirit, the goal of this project was
not to produce the “best” or “optimal” result. These terms have no meaning to a
constructionist researcher, and thus, they are not used in this study. Instead, this study
aimed to achieve “useful” results that might be refined in future studies.

In summary, just like the bricoleur seeing new possibilities for an old broomstick,
I sought to shed preconceived notions of how the experience of making is understood to
develop a culturally-contextualized makerspace. Constructionism was the chosen
epistemology for this study because the research questions lacked a single objective
answer, which required a flexible epistemological choice that allowed for the possibility
of multiple truths. Of the various epistemologies that acknowledge the existence of
multiple truths, constructionism was well-suited for this project because making artifacts
represents the physical manifestation of the construction of knowledge that occurs in
the making process.

3.3 Theoretical Perspective

Crotty (1998) defined a theoretical perspective as “the philosophical stance
informing the methodology and thus providing a context for the process and grounding
its logic and criteria” (p. 3). If the wide variety of epistemologies can be represented as
different cameras, the theoretical perspective would be the type of lens used. Due to the
nature of the population involved in this study, critical inquiry was chosen as the
theoretical perspective, which is a perspective not satisfied with the status quo. Critical
researchers see the world in terms of the oppressed and the privileged, the have and
the have nots. As such, the goal of critical research is not to simply describe. It takes a
critical look at the current situation, challenges it, and then works towards changing it (Merriam, 2009).

Critical inquiry can trace its roots back to the teachings of Karl Marx, who understood the history of humanity as a series of class struggles. He saw economics as the main factor in shaping society, often privileging one group at the expense of the others. He believed that revolution could lead to the emancipation of the oppressed, but only if they chose to destroy the social constructs that created the power imbalance in the first place and did not try to take on the role as the new oppressor. Marxism paved the way for the Institute of Social Research in Frankfurt, Germany. During the 20th century, the Institute was home to many renowned critical researchers such as Max Horkheimer, Theodor Adorno, and Jürgen Habermas (Crotty, 1998).

Brazilian educator and philosopher, Paulo Freire, was another important player in the continuing development of critical inquiry. Freire believed that humans should not simply see the world for what it is. Rather, they should see it for what it could be. Like Marx, Freire understood that it is impossible for an external party to emancipate an oppressed community. Through praxis, a parallel process of reflection and action that can be used to transform the world, a community of people can raise their conscientization, or awareness of the forces that shape their lives, so that they can rise above them (Crotty, 1998; Freire, 2000; Kincheloe & Mclaren, 2005).

One of the crucial components to increasing conscientization is dialogue. Freire criticized the “banking” transfer of knowledge, where the teacher “deposits” knowledge into the student. Instead, Freire advocated for dialogical education where the student and teacher are regarded as equals in the process of constructing knowledge together.
By giving the oppressed a voice, everyone is empowered on a mutual goal of becoming more human (Crotty, 1998; Freire, 2000). The work of Freire is highlighted in this section because it also heavily influenced PAR, the initially chosen methodology for this study. PAR is discussed in greater detail in Section 3.5.1.

Critical inquiry is a dynamic perspective, one that is constantly challenging itself, in addition to the status quo. Rather than feign impartiality, critical researchers make their biases known explicitly. Although critical inquiry can be paired with any epistemology, its allowance for the possibility of multiple realities and the construction of truth (Arminio & Hultgren, 2002) make it an appropriate partner to constructionism. Critical bricoleurs seek the methods and theories most appropriate for their study. They will not passively select the methods that are universally accepted for a particular context because they recognize that any interpretations of experience using a theory are “inseparable from the historical dynamics that have shaped it” (Kincheloe & Mclaren, 2005, p. 317). This understanding may lead critical bricoleurs to combine theories and methods from different disciplines, as it is deemed appropriate, to construct new meaning that would not be obtainable with either discipline alone.

This study embodied critical inquiry by challenging the current understanding of what making is. I did not see the state of the Navajo Nation as static. I sought to give a voice to a community that has historically been a victim of oppression—an oppression that continues in various forms. I was not satisfied with simply describing how making is a part of the Diné culture. Instead, I sought to act on this information by working with the community to design a makerspace that could improve the quality of life for the Navajo Nation.
3.4 Modification to the First Research Question

Through the experiences of living on the Navajo Nation, working with the community, and collecting and analyzing data, I grew as a critical researcher. When I reexamined the first research question, I felt that the way it was phrased was inappropriate. The original question was, *In what ways do the Navajo already exhibit maker qualities?* This question begs the following questions: Who is responsible for deciding what maker qualities are? Is it Western society? From a critical perspective, I looked to challenge the current understanding of what making is and add the Navajo Nation’s unique perspective to create a broader understanding of the experience. As a result, the research question was rephrased as follows: *In what ways do the Navajo describe the experience of making?* This question does not imply a preexisting understanding of making.

3.5 Methodology

When I first started analyzing data for this project, several factors arose that made it necessary to modify the chosen methodology in addition to the changes I made to the first research question. Both the initially chosen and final methodologies are discussed in this section. While it may appear to make more sense to simply document the final methodology implemented, there are two reasons to justify a description of both methodologies. First, one way to assess the merit of a qualitative research project is the amount of transparency that principle investigators exhibit in documenting their rationale in making decisions that affect the study. By explaining where the study started, I can provide context and allow myself to explain the motivations behind the final design choices implemented. Second, there is academic value in documenting my decision-
making process, for the lessons I learned could benefit other researchers who are interested in conducting similar studies.

3.5.1 Initially Chosen Methodology: Participatory Action Research

Native Americans are one of the most highly studied ethnic groups in the United States. There have been several cases where research has directly harmed a Native community. One of the more infamous cases occurred in the 1990s when Arizona State University conducted a research project with the Havasupai. The project involved drawing blood samples from the members of the tribe to see if their DNA was predisposed towards Type-II Diabetes, a disease that heavily afflicted the tribe. The blood samples were then distributed around the country and used for other research topics such as inbreeding and studies on migration patterns from Asia to North America without the tribe's or donors' consent (Shaffer, 2004). Not only did neither of these studies benefit the Havasupai community, but they also caused direct harm to its people. Conducting a study on inbreeding stigmatized the Havasupai people while the migration study directly undermined the religious beliefs regarding their origin (National Congress of American Indians, 2012). PAR is presented in this section as a research methodology that can help prevent further exploitation of Native communities.

PAR is a member of the classification of research known as action research. The genesis of action research is most often attributed to German-American social psychologist, Kurt Lewin, in “Action Research and Minority Problems” (Adelman, 1993). Rapoport (1970) described action research as aiming "to contribute both to the practical

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concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration within a mutually acceptable ethical framework” (p. 499).

Lewin strongly advocated for participation and democracy in action research (Coghlan & Jacobs, 2005). Participation of the community is an important element of action research for many reasons. First, the community has an intimate knowledge of the issues they face. Second, the community can help guide the action portion of the project towards interventions that are likely to receive a positive response from the community (Mohatt et al., 2004). Third, the community members will remain in the community long after the research is concluded. By involving them in a meaningful way, it gives them ownership of the project and helps to generate long-lasting change in the community.

Action research is neither a pure research project, nor is it solely an outreach project. For a study to be considered action research, it needs to generate both theory and social change. An action research study generates theory that helps explain and resolve the issues that the community faces. The theory generated is then used to guide action that transforms the community’s environment (Dickens & Watkins, 1999). As a result, action research is in a unique position to help bridge the gap between theory and practice (Hockley, Froggatt, & Heimerl, 2012).

Although action research is not inherently qualitative in nature, qualitative methods are commonly associated with it (McKernan, 2013). Another characteristic of action research is its iterative nature (Dickens & Watkins, 1999). Lewin (1946) himself described action research as “a spiral of steps each of which is composed of a circle of planning, action, and fact-finding about the result of the action” (p. 38). In the first step,
Lewin explained that the community meets to examine the issue it faces and to develop a plan for overcoming it. Next, the plan is implemented. Finally, during the fact-finding phase, the community evaluates the effectiveness of the action and also learns how to improve it. This information is then utilized to modify the next step of the process, as well as the plan for the project as a whole. The cycle begins again with the next iteration of the planning phase. However, this time the cycle has feedback from the previous iteration.

PAR, often associated with Paulo Freire (Baum, MacDougall, & Smith, 2006; Huang, 2010), is based on critical theory (Kidd & Kral, 2005). In addition to generating social change and theory, there is an additional emphasis on empowering the community to help develop these changes, which is done by directly involving the community in every phase of the research project as coresearchers instead of subjects (Arnold & Fernandez-Gimenez, 2008). This involvement helps individuals in the community become aware of their resources and develops their ability to solve problems on their own (Arieli, Friedman, & Agbaria, 2009).

### 3.5.2 Motivation for Changing the Methodology

PAR requires that the community be involved meaningfully in all aspects of the research project, including formulation of the research questions, collection of data, data analysis, and dissemination. Unfortunately, due to a variety of factors, efforts to include the community at this level of participation were unsuccessful. The first factor was the unfamiliarity of the community with both makerspaces and qualitative research. While it is possible that this obstacle could have been overcome by providing training to the community, this was not possible due to the second and perhaps the biggest preventative factor: a lack of time. Because many of the community members were
already trying to balance multiple projects, classwork, jobs, families, and care of their land, it seemed inappropriate to ask them to sacrifice a resource that they did not have for the sake of this project. The third factor was distance. Much of the initial design of the study was conducted nearly 2000 miles from the site of the project, making it nearly impossible to receive meaningful participation of the community in the early stages of the project. From a critical perspective, I did not feel that it was appropriate to label this study as PAR.

There was much variation in the ways that participants described the experience of making. As an outsider, it may be easy to regard the Navajo Nation as a homogenous community, but this perspective is far from the reality. There are many differences in the worldviews of the Diné people, which was captured in this study’s pool of participants. For example, some community members live very traditionally, while others have adopted a more Western lifestyle. During the data collection process, I often asked participants questions to determine whether they were raised traditionally. Initially, I expected their responses to be straightforward with a binary answer of “yes” or “no,” but the answers given were a lot more complicated. For example, Participant C responded, “somewhat traditionally” while Participant H mentioned that his family was “traditional when we have to be.” These participants live between two worlds and there is the potential for much variation with how these individuals try to incorporate the traditional Diné and Western ways of life into their own worldview. Variations exist even among the members of the community who live more on the traditional side of this spectrum. Participant C mentioned,

There’s a lot of conflicts within the, the reservation, you know, regarding traditions, you know. Especially with this, um, ceremony they do called the
Squaw Dance. And so, like people in Tuba City would do it different than people, um, over here [indecipherable] at Crownpoint would do it, you know, they, and, you know, sometimes they butt headed, butt heads about that, too.

As a result, this study required a methodology that could reconcile these variations.

3.5.3 Implemented Methodology: Phenomenography

Phenomenography is a research methodology that was developed by a team at the Swedish University of Göteborg during the 1970s (Pang, 2003). According to Marton (1981), phenomenography “aims at description, analysis and understanding of experiences” (p. 177). It assumes that there is variety in the ways that people may experience a given phenomenon and that these qualitatively different variations are finite (Pang, 2003). Analysis of the data produces a group of categories that collectively represent the range of different ways that a phenomenon is experienced (Sjöström, 2002). Often, they are related to one another in a hierarchical fashion. These categories and the description of the relationships among them represent the outcome space; the final results of a phenomenographic study (Jordan, 2015).

It is important that phenomenography is not confused with another similarly named qualitative research methodology known as phenomenology. As mentioned before, phenomenography attempts to describe the variations or differences in how people describe an experience. Because it is concerned with how people describe the experience of a phenomenon and not the phenomenon itself, phenomenography utilizes what Marton (1981) referred to as a second-order perspective. This perspective is contrary to phenomenology, which aims to find the commonality between the different accounts of a phenomenon to describe its essence (Sjöström, 2002). To describe this
phenomenon directly, phenomenology uses a \textit{first-order perspective} (Barnard, McCosker, & Gerber, 1999; Marton, 1981).

Semistructured interviews are the primary type of data collected in a phenomenographic study (Ornek, 2008). A semistructured interview is one with a protocol that may have predetermined questions. Still, the questions do not need to be asked in a specific order nor do they have to be phrased in a specific way (Merriam, 2009). This flexibility allows the interviewer to explore emerging ideas that the participant may present by using additional probes and follow-up questions (Merriam, 2009). It is through this interaction between the interviewer asking questions and the participants relaying their understanding of the phenomenon under investigation that new knowledge is constructed. Due to “the constructed nature of phenomenographic explanations” (Richardson, 1999, p. 68), semistructured interviews and phenomenography are epistemologically consistent with constructionism.

While an epistemology is a set of beliefs regarding the nature of knowledge, an ontology is a set of beliefs regarding the nature of reality (Merriam, 2009). Inherent to phenomenography is the ontological assumption that the world is nondualistic. As Marton and Booth (1997) explained,

\begin{quote}
The world is not constructed by the learner, nor is it imposed upon her; it is \textit{constituted} as an internal relation between them. There is only one world, but it is a world that we experience, a world in which we live, a world that is ours. (p. 13)
\end{quote}

Simply put, there is not an objective world outside of human consciousness existing in parallel with a subjective world existing within everyone. While all people may experience the world differently, there still exists only one world. The first part of the quote, “the world is not constructed by the learner” (Marton & Booth, 1997, p. 13),
appears to be in conflict with constructionism. It should be noted that nondualism is an ontological belief that concerns the nature of reality and not an epistemological belief concerned with the nature of knowledge.

A major implication of this ontological assumption is that the results of a phenomenographic study are sensitive to the context in which the study was conducted. Factors like the dynamics between the researcher and the participant, the experience of the researcher, any predisposed biases that the researcher may have had, and so on, have an impact on which part of the outcome space of a phenomenon is illuminated. As described by Walther, Sochacka, and Kellam (2013), “This nondualistic assumption that researcher and respondents are linked as parts of the same lived experience means that a specific, contextual version of the social reality is constructed in the data gathering situation” (p. 634). As a result, phenomenography requires an epistemology, like constructionism, to reconcile the possibility that two studies with identical designs but performed in different contexts could reveal different aspects of the outcome space.

It should be noted that constructionism is not the only epistemology that may be paired with phenomenography. The unique nature of each qualitative research project makes it critical that the researcher choose components of the research design that complement each other in the context of the study. It is also important that researchers document their motivations and decision-making process explicitly to allow the reader to determine whether these choices were justified.

One of the major criticisms during the initial years of phenomenography as a research methodology was that while it was able to describe the different variations that people experience in a given phenomenon, its lack of a theoretical foundation prevented
it from explaining the cause of these variations (Bussey, Orgill, & Crippen, 2013; Micari, Light, Calkins, & Streitwieser, 2007). This issue motivated researchers in the 1990s to pursue the development of variation theory (Bussey et al., 2013). The theory posits that while every phenomenon is, as Pang (2003) described, “infinitely complex” (p. 148), it can be defined by a finite number of critical features (Pang, 2003). It is only possible for people to become aware of a critical feature if they experience variation in that feature (Orgill, 2012). Which features individuals pay attention to while experiencing the phenomenon will determine how they describe it (Pang, 2003).

The following example can help illustrate how this works. There are a finite number of critical features defining the experience of eating chocolate ice cream. Some of these critical features include taste, texture, temperature, and so on. Now imagine that someone eats a spoonful of hot chocolate and then a spoonful of chocolate ice cream in succession. He or she is then asked to describe the experience of eating ice cream. The difference, or variation, of the temperature between the hot chocolate and the ice cream would cause that critical feature to come to the foreground. Other critical features, such as the taste of chocolate, would remain in the background, which would likely cause the individual to describe the experience of eating chocolate ice cream in terms of how cold it is.

In a second experiment, another individual first eats a spoonful of cold sour cream before eating the ice cream. If he or she were asked to describe the experience of eating the ice cream, the individual would likely focus on the sweet taste of chocolate, for this critical aspect was brought to his or her awareness due to the variation of taste with the sour cream. This example demonstrates how two people could both describe
their experience of eating chocolate ice cream in two very different ways. Through these descriptions, it becomes possible to determine the different critical aspects that define the phenomenon. While phenomenography can determine the variations found in how people describe their experience of a phenomenon, variation theory provides the theoretical foundation that explains why these variations exist. In summary, this project required a methodology that could reconcile the variation in the ways that participants described the experience of making, for which phenomenography was an apt choice.

3.6 Research Methods

3.6.1 Site Description

Prior to discussing the details of the research methods that were implemented for this project, it is important to first provide the context in which this study was conducted: Crownpoint, New Mexico. Crownpoint is a small rural community within the Eastern Agency of the Navajo Nation with a population of just over 2,000 people (U.S. Census Bureau, 2010). Located in the town is the main campus of NTU. This location was partly chosen due to NTU’s preexisting interest in making in the forms of their Fabrication Lab and the encouragement students receive to present at Maker Faires. In addition to these Western understandings of making, traditional Diné making is also present. For example, Crownpoint is also home to the monthly Crownpoint Navajo Rug Auction. Between the NTU students’ understandings of making as well as those from Crownpoint community members, I believed it possible to get a glimpse of the full spectrum of how the Diné people understand the concept of making.

3.6.2 Role of the Researcher

The qualitative researcher plays the important role of the primary measurement instrument in the data collection and analysis. However, researchers may play
additional roles depending on their relationship with the community. One option is that researchers are completely removed from the community. Outsider researchers collect and analyze data from afar and do not participate in any community activities, which helps them to maintain objectivity and allows them to see the “big picture” regarding the interrelatedness of patterns. However, the distance may also make it difficult for these researchers to relate to the experiences of the community.

The other stance is a researcher who is intimately connected to the community. The community may have an increased level of trust with these insider researchers, which can create access to data and insights that would otherwise be unavailable to outsider researchers. However, the dual role of active community member and researcher can cause role confusion and create a conflict of interest.

Dwyer and Buckle (2009) discussed the fallacy in the belief that the role of the researcher is a binary category consisting of insider or outsider. Instead, they described the space between these two extremes. My history in working with the Navajo Nation made it impossible for me to completely detach myself emotionally from the community. However, in many ways I remained an outsider to the Crownpoint community. During the study, I struggled to find housing arrangements in Crownpoint, so I lived near the capital of the Navajo Nation, just over 60 miles away, which meant that my time in Crownpoint was restricted to only activities related to research and work. Additionally, while I respect the Diné way of life and their beliefs, I do not identify them as my own. As a result, it was in this gray area that I operated during the study, a position neither beneficial to the study nor a hindrance. It simply was. Perhaps Dwyer and Buckle (2009) described it best when they explained the role of researchers is not as important as their...
“ability to be open, authentic, honest, deeply interested in the experience of one’s research participants, and committed to accurately and adequately representing their experience” (p. 59).

As mentioned in Section 3.5.1, there is a history of exploitation and irresponsible research conducted on Native American communities. As an external researcher who did not wish to continue this trend, I attempted to keep the needs and interests of the community as the highest priority while I conducted this investigation. In some cases, the needs of the community conflicted with the needs of the research project. For example, one of the reasons that NTU was interested in supporting the study was that I agreed to offer my services assisting their students throughout the semester. At the time, there was a great need for additional faculty to teach courses, so NTU asked me to teach and develop the curriculum for an elective. Initially I declined because teaching potential participants of the study would change the dynamics of the relationship between interviewer and participant. It created a power difference that could have affected how the participants responded during the interviews, and I did not feel that it was in the best interest of the study. However, after critical reflection, I realized the danger of putting the study’s interests before the community’s, so I decided to teach the course. While I believe that this decision was ultimately the right one, it may have had an impact on the study because nearly half of the participants were students in the course I taught.

3.6.3 Participant Recruitment

The goal of recruitment was to find a pool of participants who represented all of the project’s potential stakeholders: community leaders, artisans, artists, teachers, engineers, students, entrepreneurs, etc. As a result, participants were purposefully
selected to allow for the inclusion of members of the community with experiences and backgrounds that allowed them to address the research questions. Participants were recruited by four methods. The first method I implemented was soliciting for participants at the Crownpoint Chapter’s monthly meetings. The second method involved sending a recruitment e-mail out to the NTU student body twice during the period of data collection. The third method was through recommendations from community gatekeepers such as professors at NTU. The fourth and final method utilized “snowball” sampling, a technique through which new participants are introduced to the study through the recommendations of those that are currently a part of it (Merriam, 2009). This method may provide access to people and data that would otherwise be inaccessible.

While collecting data, it was very difficult to find participants that both had knowledge in making and lived in Crownpoint. Crownpoint is a very small community and many of the students at NTU commuted from outside of town. As a result, the participant pool was expanded to include NTU students who lived in other communities.

3.6.4 Participant Description

A total of 18 participants were interviewed in this study: 17 students from NTU and one nonstudent who is a member of the Crownpoint community. All participants were 18 years or older and identified as being Navajo. With regards to gender, seven of the participants were female while 11 were male. The NTU students self-identified as studying a variety of different disciplines including Electrical Engineering; Diné Culture, Language, and Leadership; Mathematics; Building Information Modeling; Computer Science; Industrial Engineering; Early Education; and Metrology.
Because those conducting phenomenographic studies are interested in the range of different ways that a group of people describe their experience of a phenomenon, it is appropriate for them to purposefully select a diverse set of participants (Adams, Daly, Mann, & Dall'Alba, 2011). As mentioned in Section 3.5.2, there was a lot of variation in whether or not the participants identified as being traditional. Additionally, while nearly all of the participants in this group had a common role in being a student, it is important to note that this group also consisted of rug weavers, gardeners, carpenters, cooks, teachers, hair stylists, fathers, mothers, musicians, landscapers, actresses, entrepreneurs, composers, mechanics, basket weavers, and silversmiths.

3.6.5 Data Collection

Prior to collecting data, this study was approved by the Navajo Nation Human Research and Review Board (NNHRRB) as well as the University of Florida’s Institutional Review Board (IRB). The NNHRRB is an independent IRB that exercises the Navajo Nation’s “sovereign rights to regulate, monitor, and control all research within the boundaries of the Navajo Nation” (Becenti-Pigman, n.d.). The University of Florida’s IRB is not sufficient to ensure protection for the Diné people because the board has no knowledge of the needs or interests of the Diné community (Lomawaima, 2000). Any published materials from research projects conducted on the Navajo Nation must be reviewed and approved by the NNHRRB, which allows the Navajo Nation to retain control over how their people and their culture are presented to the outside world. A copy of the approval letters from the NNHRRB and University of Florida’s IRB may be found in Appendix A and Appendix B, respectively. To receive approval from the NNHRRB, I had to also receive a permit from the Navajo Nation Historic Preservation Department, a resolution letter from the Crownpoint Chapter, and a letter of support.
from the president of NTU. Copies of these documents can be found in Appendices C, D, and E, respectively.

As mentioned previously, the primary method of data collection that was used in this study was the semistructured interview. Semistructured interviews are exploratory (Svensson, 1997) and conversational in nature (Micari et al., 2007). Ornek (2008) described the goal of these interviews:

To have the participant reflect on his/her experiences and then relate those experiences to the interviewer in such a way that the two come to a mutual understanding about the meanings of the experiences (or of the account of the experiences). (Orgill, 2002). (p. 5)

The protocol for these types of interviews feature open-ended questions that “seek to understand the participant’s meaning, not to judge his or her knowledge against an external standard” (Micari et al., 2007, p. 473). It is also important not to use leading prompts when conducting interviews to avoid influencing the participants to respond in a certain way (Richardson, 1999).

The interviews were conducted on the Navajo Nation in quiet locations that were convenient and comfortable for the participants. These interviews were audio recorded, transcribed, and lasted an average of 48 minutes; the shortest interview was 19 minutes and the longest one an hour and 24 minutes. Participants were each given pseudonyms and all identifiers were removed from the transcripts. A more detailed explanation for how I handled the issue of confidentiality in this project is presented in Section 3.6.6. All participants were informed of their rights in the study by means of an informed consent form which can be found in Appendix F.

During the interviews, participants were asked questions regarding how they described the experience of making. Because I sought to challenge the current
understanding of making, the term *making* was not defined to participants to allow them to define it on their own terms. The data collected from the interviews served three purposes. First, they addressed the first research question: *In what ways do the Navajo describe the experience of making?* Second, the results of the initial interviews were used to inform the direction of subsequent ones. After each interview, I wrote about it in my reflexivity journal. A reflexivity journal is a document where, as a researcher, one would write “your reflections, your questions, and the decisions you make with regard to problems, issues, or ideas you encounter in collecting data” (Merriam, 2009, p. 223). This thoughtful reflection helped to inform the data collection process by motivating the reprioritization, rewording, and removal of the different questions in the protocol. Third, these interviews were also the primary source of data that was used to address the second research question.

Making a modification to the research question after the data had been collected had a significant impact on the study (i.e., large portions of certain interviews did not contain information relevant to the modified question). Had the modified question been used from the start of the project, it may have altered which questions were included in the interview protocol, changing what aspects of the outcome space were illuminated. For the complete interview protocol used in this study, see Appendix G.

### 3.6.6 Concerns with Confidentiality

To protect the identities of the participants involved in the study, pseudonyms were assigned after all of the data had been collected. The simplest solution would have been to use an online random name generator. However, these name generators tend to contain a bank of primarily Western names. From a critical standpoint, it seemed inappropriate to challenge the prevailing understanding of making by assigning names
to the participants from the dominant culture. Such an assignment of names would only further perpetuate colonialism and imply that the only voices that should be valued in the academic world are those that come from people with Western names. A better solution is to use names that reflect the community that the participants represent, but this also presents some issues.

Because of colonialism, many of the community members do have Western names, and those who do not tend to have very unique ones. Possibly the best solution is to involve the participants in the pseudonym assignment process. However, because the pseudonyms were assigned after the data had already been collected, it was not an option. Without knowing how to proceed, I sought feedback from the community and spoke with a representative from the NNHRRB who suggested using some sort of code. Eventually we both agreed on using a letter of the alphabet to designate each participant. A unique random letter was assigned to each participant with certain letters like A and I removed from the pool of potential pseudonyms because they also represent words and may have caused confusion. The letter Q was also reserved to designate the interviewer in the transcripts. Although this assignment method satisfied the NNHRRB, I feel that it dehumanized the participants. While it was important to respect the wishes of the community by using the letter assignment method for this study, in future studies, I would like to have a conversation with the community to determine a better way of assigning pseudonyms.

All transcriptions were deidentified while verifying their accuracy. Information such as names, ages, employers, number of years spent studying at NTU, and hometowns were removed to make it impossible for someone outside of the community
to be able to identify the participants. After verification of the interviews, I continued to remain vigilant throughout data analysis in the search for any previously unnoticed identifying information. This state of constant awareness while handling the data helped to ensure that the identities of all study participants were kept confidential to the external community.

While it is possible to deidentify a transcript for the external population, it is extremely difficult to do so for community members. Despite using codes or pseudonyms, some of the experiences described by the participants were so specific, anyone who knew the participant well enough would be able to identify them. For example, if a participant described an experience of how he or she was able to travel to Tanzania to work on a project, it would not be difficult for someone from the community to identify this individual. One solution would have been to remove all information of this nature from the transcripts, which presents two problems. First, large portions of the transcript would have been removed, potentially destroying the context in which a participant’s comments are situated, distorting the data. Second, it would have been very difficult for an external researcher to determine every possible piece of information that could be used by a community member to identify a participant. This risk is part of conducting a qualitative research project. Fortunately, the information collected in this study is not of a particularly sensitive nature.

In many studies, researchers protect their participants from this sensitive situation by limiting who has access to the data and by destroying the data once the study is complete. All of the data collected in this study, including transcriptions and audio data, remain the property of the Navajo Nation and will be indefinitely maintained.
in an archive. While this protocol was conveyed explicitly to all participants prior to their interview through the informed consent form, I am concerned that once the data are transferred to this archive, I cannot guarantee the confidentiality of the study’s participants. In addition to being able to identify participants through their accounts of unique experiences, it is also possible that someone from the community could identify someone in the audio recordings by recognizing his or her voice. I spoke with a representative from the NNHRRB to express my concerns. Their response was that once the data are submitted to the archive, it becomes the responsibility of the Navajo Nation to maintain the confidentiality promised in the informed consent form.

3.6.7 Transcription and Verification Procedure

Originally, I had planned to transcribe the interviews in parallel with the data collection process. However, after spending more time with the community and learning their needs, I felt that it was more appropriate for me to outsource the majority of the transcription process to devote more time towards activities like working with the NTU students on their projects and developing the course at NTU that I was asked to teach. The interviews were transcribed by three different people; 15 by two transcriptionists who worked at different external transcription services, and three by myself.

The transcription and verification process occurred in four steps. In the first step, either I or an external transcription service transcribed the interviews verbatim. The second step involved personally going through each transcription and standardizing the format. Third, I read each transcript in its entirety while listening to the audio recording at reduced speed to deidentify the transcripts and rectify any misinterpretations. During the fourth and final step, I read each transcript in its entirety while listening to the audio recording at normal speed to verify the accuracy of the transcription. I conservatively
estimate that I personally spent over 250 hours transcribing, verifying, and deidentifying the transcripts.

Due to the external transcriptionists’ lack of knowledge regarding the context in which the interviews were conducted, their transcripts required close examination to verify their accuracy. In some cases, the participants spoke in Navajo or made a reference about the culture that the external transcriptionists misinterpreted due to their lack of understanding of the community. For example, in one interview, a participant talked about how the Diné believe that they learned to weave from Spider Woman. The external transcriptionist misinterpreted these words by writing that Spider Woman taught the Diné to read. It is understandable how someone could mistake one of these similar sounding words for the other without any knowledge of the context of the conversation.

3.6.8 Data Analysis

While there is no prescribed method for analyzing data in a phenomenographic study, I synthesized the analysis method used in this study from Åkerlind’s (2012) article on the variations and commonalities present in phenomenographic research methods. Prior to analyzing the data, it was important that I first familiarize myself with them, a step that involved reading through the transcripts multiple times without any preconceived ideas about what I expected to find. After the transcripts had been read multiple times, I searched for any quotes that potentially addressed the research question. One of the critical aspects of phenomenographic data analysis is that the interviews are analyzed as a group rather than as individual responses. As a result, such quotes were then put into a collective pool of data. As Åkerlind (2012) noted,

The aim is not to capture any particular individual’s understanding, but to capture the range of understandings within a particular group. The interpretation is, thus, based on the interviews (more precisely, the
interview transcripts) as a holistic group, not as a series of individual interviews. (p. 124)

Context is extremely important when conducting this type of data analysis and it can sometimes be lost when gathering the quotes. Svensson (1997) described how two quotes can use very similar words to say two entirely different things once the context for each quote is revealed. The converse is also true in that participants might say something with the same meaning but use a very different vocabulary (Svensson, 1997). As a result, if the context of a quote was unclear when I placed it into the data pool, I paired the quote with a short description of the context in which that quote was said.

From this pool, the data were then sorted into emergent categories (Yates, Partridge, & Bruce, 2012). Each category represented a unique way in which the participants described the experience of making. Next, I discussed these emerging categories with another researcher to triangulate the initial findings and to provide additional refinement. Afterwards, I independently determined all of the categories that each transcript represents. For example, the first category was characterized by the role that making has played in the survival of the Diné people. If a participant described the financial benefit of making during his or her interview, the transcript would be grouped into this category. This same transcript could be grouped into other categories as well based on additional evidence (i.e., the participant also acknowledged the social aspect of making). This process of assigning categories to each transcript helped to verify that the full range of how the participants described the experience of making was captured. It also helped to determine the important features that defined the boundaries of each
category. Additionally, this process also illuminated the emerging logical hierarchical relationship among the categories.

The second researcher and I once again discussed the categories until they appeared to stabilize. The preliminary outcome space was then presented to community members from the Navajo Nation to receive their feedback before the outcome space was finalized. A depiction of the data analysis process is shown in Figure 3-2.

3.7 Theoretical Framework

Merriam (2009) defined the theoretical framework of a study as “the underlying structure, the scaffolding or frame of your study” (p. 66). Often discipline dependent, it is how the theory connects to existing theoretical foundations. This framework may be derived from literature, it may emerge from the data in the study, or a study may have no framework at all. The point at which a framework is chosen depends on the study itself. Shehab et al. (2015) waited until themes emerged in the data analysis before selecting a framework that complemented these themes. Similarly, I allowed the theoretical framework to naturally emerge during the data analysis process. For this study, Maslow’s (1943) theory of human motivation was selected.

It is important to note that this study was not designed with Maslow’s framework in mind. Instead, the theoretical framework naturally emerged during the data analysis process. During data analysis, I found that the participants often used their motivation to make as the context for describing their understanding of making. I chose this framework for the study because the different motivations of the participants generated categories of making that aligned well with Maslow’s theory. From a critical standpoint, one might question whether it was appropriate to use a framework that was not derived by the community. This is a valid and important concern addressed in Section 3.9.
Figure 3-2. Phenomenographic data analysis process
3.8 Quality

In a quantitative study, quality is evaluated on criteria like internal validity, external validity, reliability, and objectivity. Criteria that assume one measurable reality, like objectivity, are not appropriate for studies designed with an epistemology that allows for multiple realities. However, Guba (1981) posited that these criteria of trustworthiness are merely the quantitative manifestation of the more general aspects of truth value, applicability, consistency, and neutrality. Guba continued to propose that the qualitative representation of these aspects might be described as credibility, transferability, dependability, and confirmability. In addition to discussing these criteria in detail, this section also presents the research strategies that were used to combat any potential threats to quality in this study.

The first criteria to be discussed is truth value (Guba, 1981). The quantitative manifestation of this criterion is internal validity, which is the extent to which inferences regarding causality can be trusted within a study (Shadish, Cook, & Campbell, 2002). Similarly, for the given data in a qualitative study, credibility is the extent to which the findings of the study are plausible (Chism, Douglas, & Hilson Jr., 2008). One strategy a qualitative researcher can use to increase credibility is to triangulate the findings by analyzing the data with multiple researchers (Merriam, 2009). For example, in this study, I analyzed the data with a researcher from Tufts University. Our initial data analysis was conducted independently. Once we had adequate time to analyze the data, the emerging categories and relationships among them were discussed until we reached a consensus.

Another method to increase credibility in a study is member checking (Chism et al., 2008). Lincoln and Guba (1985) defined member checking as the process, “whereby
data, analytic categories, interpretations, and conclusions are tested with members of those stakeholding groups from whom the data were originally collected” (p. 314).

Member checking is a form of feedback, a dialogue between the researchers and the participants after the interview. In this dialogue, researchers describe their understanding of the constructed reality that the participants described to them (Cho & Trent, 2006). The participants then have the opportunity to confirm or clarify the researchers’ interpretation of their reality (Cho & Trent, 2006). Member checks were originally considered for this study but were not implemented due to the methodological change from PAR to phenomenography. Phenomenography’s nondualistic assumption makes it clear that a participant’s understanding of an experience is context sensitive. Because their understanding of an experience may have changed since the initial interview, member checks in phenomenographic studies are not considered appropriate (Åkerlind, 2012).

The second criterion is applicability (Guba, 1981). Its quantitative representation, external validity is the extent to which a study’s findings can be generalized outside of the context of the study (Shadish et al., 2002). Quantitative studies emphasize random sampling to ensure that, within the bounds of sampling error, the sample is an accurate representation of the larger population from which it is drawn (Shadish et al., 2002). Thus, the more closely that a sample represents the population, the more one can generalize findings from the sample to the population. In qualitative studies, researchers are looking for new understanding on a specific topic. As a result, it is more appropriate to use purposeful sampling and include people in the study who have backgrounds and experiences that can help answer the research questions (Merriam, 2009).
Because the community members who participated in this study were not randomly chosen, they were likely not representative of the larger population, making it difficult to make any claims regarding generalizability. Instead, qualitative researchers may attempt to determine the transferability of a study (Merriam, 2009). When researchers use thick, rich descriptions, readers can gain insight on whether the findings of a particular study are transferable to their own situations (Merriam, 2009). Another way to look at it is, “quantitative research places the burden of demonstrating generalizability on the researcher, while qualitative research places the burden of identifying appropriate contexts for transferability on the reader” (Borrego et al., 2009, p. 57).

The third criteria, consistency, takes the form of reliability in a quantitative study (Guba, 1981). Reliability is the extent to which a study can be reproduced (Merriam, 2009). From an objectivist epistemological stance, one that assumes that there is only one objective Truth, it is important that a replicated study produces the same results. Qualitative research, on the other hand, acknowledges that showing reliability in studies involving people is impossible because they are inherently dynamic and rooted in the context of the project. For example, the same researcher could conduct the same qualitative study at different points in their life and come up with completely different findings (Stewart, 2010). As a result, qualitative researchers are not interested in reliability, but rather dependability (Merriam, 2009).

In the context of qualitative research, multiple researchers could interpret the exact same data differently, and both accounts would be considered dependable if they were both consistent with the data (Merriam, 2009). One way to ensure dependability is
to create an audit trail, allowing the reader to audit the researcher’s decision-making process to discern the degree to which the study can be considered dependable (Chism et al., 2008). As mentioned in Section 3.6.5, throughout this research project, I wrote in a reflexivity journal. In this journal, I documented the motivations for various decisions that I made in the project. While it was not possible to include the entire journal that I generated in this document, I have included pieces adapted from it to be explicit about my motivations and to provide the rationale for the various decisions that I made while conducting the study. For example, Section 3.4 was adapted from my reflexivity journal.

The last criteria to be discussed is neutrality (Guba, 1981). Quantitative researchers know this criterion as objectivity, or the extent to which a researcher’s biases have been removed from the study (Guba, 1981). Similarly, the qualitative equivalent, confirmability, is the extent to which the findings of a study reflect the data and not the biases of the researcher (Shenton, 2004). Just as it is important to identify any biases in the measurement instruments of a quantitative study, the measuring instrument in qualitative studies, the researchers, must also disclose their own personal biases which may affect the study (Creswell & Miller, 2000). While it is never possible to eliminate these biases completely, by being aware and transparent about them, the researcher may help the reader understand the ways these biases affected the study. For example, in the subjectivity statement presented in Section 3.9, I reflect upon my own biases which affected the study. Even if it were possible to eliminate all biases, such a process would be inappropriate in a critical study because the researcher’s desire to generate change implies a certain bias (Chism et al., 2008).
A summary of Guba’s qualitative criteria for trustworthiness, the quantitative equivalents, and the strategies this study utilized for protecting against threats to quality are shown in Table 3-1. It should be noted that Guba’s criteria for assessing the trustworthiness of a study are not universally accepted in the qualitative research community. Critics of Guba’s typology argue that terms like credibility merely put a qualitative wrapper on an inherently objectivist concept, and are therefore inappropriate to apply to qualitative research because they are based on different epistemological beliefs (Sparkes, 2001; Whittemore, Chase, & Mandle, 2001). Rather than imposing a singular standard when it comes to developing criteria for assessing the quality of qualitative research, some researchers advocate for a diversity of criteria that resonate with the study’s choice of epistemology and theoretical perspective (Sparkes, 2001).

Although some researchers may disagree with Guba’s typology of criteria for trustworthiness, I saw it as being appropriate for a qualitative study in a field dominated by quantitative research, for it helps to bridge the gap between qualitative and quantitative research.

Another measure of quality in a study is how clearly the researchers identified the elements of their design and explained how each are in harmony with each other (Arminio & Hultgren, 2002). Throughout this chapter, examples of how each of these research elements is consistent with the others were made. For example, constructionism was chosen to address the first research question because it required the flexibility of an epistemology that allows for multiple truths. While not an exhaustive list, Table 3-2 demonstrates examples of consistency between each of the design elements.
### Table 3-1. Common criteria for quality in quantitative and qualitative research and the strategies this study used to protect against threats to quality

<table>
<thead>
<tr>
<th>Quantitative Criteria</th>
<th>Qualitative Criteria</th>
<th>Strategy Utilized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal Validity - extent to which inferences about causality can be trusted(^a)</td>
<td>Credibility - extent to which a study’s findings are plausible(^b)</td>
<td>Triangulation</td>
</tr>
<tr>
<td>External Validity - extent to which a study’s findings can be generalized(^a)</td>
<td>Transferability - extent to which a study’s findings are transferable to the reader’s situation(^c)</td>
<td>Thick, rich descriptions</td>
</tr>
<tr>
<td>Reliability - extent to which the study can be reproduced(^c)</td>
<td>Dependability - extent to which the study’s findings are consistent with the data(^c)</td>
<td>Audit trail</td>
</tr>
<tr>
<td>Objectivity - extent to which the researcher’s biases have been removed from the study(^d)</td>
<td>Confirmability - extent to which the findings of a study reflect the data and not the biases of the researcher(^e)</td>
<td>Subjectivity Statement</td>
</tr>
</tbody>
</table>


### 3.9 Subjectivity Statement

In a quantitative research study, it is important to identify any biases in the measuring instruments used in the study to ensure accurate data. Similarly, in a qualitative study where researchers are the primary instrument for data collection and analysis, it is important for them to be transparent about any potential biases that may affect how they collect and analyze the data. This openness can help researchers to mitigate the effects that these biases may have on the research as well as allow the reader to determine the context in which the findings were made. After critical self-reflection, I have identified three instances in which these biases affected the outcome of the study. In this section, I discuss these instances in addition to the strategies that I implemented to try to mitigate their effect on the results.
Table 3-2. Justification of consistency in the research design of the first research question

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Epistemology: Constructionism</th>
<th>Theoretical Perspective: Critical Inquiry</th>
<th>Methodology: Phenomenography</th>
<th>Methods: Semistructured Interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allows for the possibility of multiple truths</td>
<td>Question challenges the prevailing understanding of making</td>
<td>Methodology addresses the wide variety of ways that the Diné describe the experience of making</td>
<td>These methods are suited to create understanding of abstract phenomena that are not easily quantified</td>
<td></td>
</tr>
<tr>
<td>Challenges conventional research design by allowing for the construction of a design that includes pieces from multiple disciplines</td>
<td>Has the ability to reconcile the possibility of multiple truths</td>
<td>Knowledge is constructed through the interaction of researchers and participants</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Helps the Navajo Nation to add their voice to how the experience of making is understood</td>
<td>Questions are phrased in a way that allows participants to answer questions in their own terms without being influenced by prevailing understandings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allows participants to qualitatively describe their experience of making</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
One of the objectives of this study was to challenge the prevailing understanding of what constitutes making. As a mechanical engineering student who has worked in several makerspaces designed for the creation of physical objects that serve engineering purposes, I also had certain beliefs regarding making at the start of the study that needed to be challenged. While I knew the Diné understanding of making would probably be different than my own, my beliefs affected the types of questions that I included in the interview protocol. For example, my own bias prevented me from considering the following question which was eventually revealed during the data analysis process: Who do the Navajo make? While it seems like an odd question to consider, it actually turned out to be very important for the findings of this study.

Due to my experience of working in various makerspaces, I saw the physical artifacts that I made as being the ultimate products of these spaces. I failed to consider the mechanical engineer that these makerspaces were helping me to become in the process of making artifacts. Had I been aware of this concept at the start of the study, I would have adjusted the interview protocol to include questions that directly addressed such a concept.

I was able to stumble upon this aspect of making despite my bias through several strategies that I had implemented in the interview process. During the interviews, I asked broad questions to allow the participants to describe the experience of making on their own terms. I also listened to their descriptions attentively, even if they conflicted with my own understanding of making. Finally, at the end of each interview, I asked the participants if they had any additional thoughts that they would like to share. This step allowed the participants the opportunity to talk about anything related to their
understanding of making that perhaps was not addressed in the questions that I asked in the protocol.

The next bias that affected the study is that I am a proponent of makerspaces. I believe that promoting STEM education, whether it be through makerspaces or other initiatives, is a worthwhile endeavor, which led me to choose Crownpoint as the site for the study. Crownpoint is the home of NTU, where students work and take classes in what might be considered a typical Western makerspace. Many of these students are also encouraged to participate in Maker Faires at both the local and national level. I chose a sample of participants who not only held many of the same biases regarding making that I had, but many of them also shared the sense of value in education. This choice, while not necessarily a wrong one, did affect which portion of the outcome space was revealed. To address this bias, I interviewed students in programs other than engineering as well as a nonstudent who was a member of the Crownpoint community.

While the first two examples demonstrated how my own personal biases affected how data were collected and who was included in the study, the final set of biases influenced the way in which the data were analyzed. For this type of project, two types of theoretical frameworks could be implemented: one derived from the literature or one derived from the community. While conducting the literature review, I encountered a community derived framework that I initially thought might be a good fit for this study. However, as an outsider to the Navajo Nation, I felt that no matter how well this framework might fit this study, it was not appropriate for my use. This community derived framework was rooted directly in the Diné culture. As a result, it was developed by hundreds of thousands of people over the course of hundreds of years. It is rooted in
lived experiences that cannot accurately be understood by simply reading about it. Any attempt that I made to use this framework would be a cheap imitation and carried a high risk of misrepresenting the Diné culture. As a result, the only other option I had was to use a framework derived from the literature.

Despite the enormous wealth of frameworks that can be found in the literature, the only frameworks that I could choose from were the ones of which I was aware. Since my studies as an undergraduate, I have been interested in the psychology field. This interest led to an awareness of Maslow’s theory of human motivation, making it a potential option in my search for a framework. During the data analysis process, I noticed that the way in which the participants were describing the phenomenon of making seemed to resonate with the hierarchy of needs presented in Maslow’s theory. I initially suppressed this thought to keep an open mind. I was afraid that I was biased towards choosing this framework because it related to a topic in which I was interested rather than it being an appropriate choice for the data. To help mitigate this bias, I used the method of triangulation as described in Section 3.8.

3.10 Summary

In this chapter, an overview of the characteristics of qualitative research was provided. The five research elements were then defined, and justifications were provided for how they were selected in this study. The qualitative nature of this project’s design allowed for flexibility when unforeseen events made it necessary to make modifications to the study. After presenting and justifying these modifications, the concept of quality was defined within the context of this study, and the strategies used to make the study more rigorous were presented. This chapter then concluded with a subjectivity statement that identified three separate instances where my biases had a
direct impact upon the study. I then detailed the strategies I used to address these biases.
CHAPTER 4
FINDINGS OF THE FIRST RESEARCH QUESTION

This chapter presents the findings that pertain to the first research question generated through the data analysis process described in Section 3.6.8. As mentioned in Section 3.4, the first research question was modified as follows: In what ways do the Navajo describe the experience of making? Implicit to this question is the following one: Why do the Navajo make? This implied question is answered through a description of the outcome space that was determined using phenomenographic analysis of the transcripts.

4.1 Results

Five distinct categories and one overarching category concerning how the Navajo describe the experience of making emerged from the data analysis. With the exception of the overarching theme, the categories form a logical hierarchy that resonates with the hierarchy of needs developed by Maslow (1943). The hierarchical categories of survival, society, pride, self-actualization, and transcendence are modeled as an inverted pyramid. The more basic or superficial understandings of making lie at the top of the pyramid. As one travels down the hierarchy, deeper and more meaningful understandings of making are represented. The overarching theme, spirituality, appears to exist independently of the hierarchy and is depicted as surrounding the pyramid rather than being a part of it. A model of the outcome space that resulted from this study is depicted in Figure 4-1.
4.1.1 Categories of Description

Survival. The first category represents the most basic understanding of making and is associated with the physiological and safety needs in Maslow’s (1943) hierarchy. Participants who described this understanding of making emphasized the act of making...
physical artifacts to satisfy lower-level needs to survive. When asked to describe the role that making plays in the Navajo culture, Participant J responded:

Oh, we’ve always, I think it was always in our tradition way back in the Long Walk, maybe even before that. When they made, they were makers of stone. They were makers of bricks. They were a maker of living, to stay alive and to eat. They, they, they made fields and fields of fruits and vegetables to stay alive.3

Participant D also described making as a means for the Diné people of the past to survive in their environment: “They had to make, like, weapons. They made, uh, clothes. They made, uh, different, whatever they had, uh, whatever materials they had they had to, they had to use to make whatever, um, to survive, you know.” This tradition even continues today as Participant S discussed how making is still important for the Navajo Nation, for it provides many people with a source of income: “I think it plays a big role in the Navajo culture because I see, like, a not, a lot of Navajo that are trying to do something mainly I think probably because it'll help them financially.”

Surviving in an environment where basic resources may be scarce has had implications for how the Diné approach making. Participant U described the importance of maximizing the utility out of available resources:

I guess before we were colonized like we were very self-sufficient. We made everything and like you look at a sheep when we butcher, everything is used and like nothing, the bones are left out but like, like intestines, everything is used, and their wool is used to make our rugs, clothes. Um, we made everything back then. Houses, we made our own houses out of the earth. Nothing was wasted.

3 While the transcripts were analyzed in verbatim form, I felt that including affirmations from the interviewer such as “mmHmm,” “right,” “yeah,” etc. as well as the interviewer’s indecipherable comments and laughter would be distracting to the reader and were therefore removed for this document.
This same lack of resources has also inspired the Diné to develop a high level of ingenuity. The expression, “necessity is the mother of invention” seemed appropriate as Participant T described how the lack of available resources necessitated that he learn to become a maker:

Growing up we didn’t have a whole lot of resources. We didn’t have a whole lot of things. Um, so therefore we didn’t have the luxuries of, um, getting certain things done with the right tool so there was a lot of let’s, let’s make something that will work like the tool that’s needed, but, you know, it, it’s going to be of our own design.

Similarly, when Participant W was asked what motivated him to make new devices, he responded:

It was like hitting a, hitting a brick wall that you had to, you had to get, you had to get over it in order to get the project done so, and it wasn’t like Auto Zone was right down the street. You had to go at least over 100 miles to get to the parts store, so you pretty much had to create your own tools or improvise something to get there.

To survive in this changing world, Participant E expressed that the way in which things are made on the Navajo Nation is also changing:

It’s for survival. Um, you know, like, like making is like changing. Um, even the way that we make this-, make these cultural items, you know, um, like my loom, like my sash belt loom. I bought the supplies from it for Home Depot, from Home Depot [indecipherable]. . . . I don’t go and sheer sheep and you know, card the wool and spin it, you know, like my grandma did, you know. So, the way that we make things is also changing.

Several participants noted that the knowledge of how to make things was passed down traditionally to help the next generation survive. For example, Participant B stated,

It’s mostly teachings that they’re trying to pass down. And so, when they pass it down, you know, they’re getting the knowledge to make the things that they’re trying to teach. Like the rugs and the clothes, the rug dresses, and there’s, I don’t know if they still make moccasins but there’s the cakes and then there’s all the traditional stuff that they use in the ceremonies. They have to learn how to make that, too. And I guess back then they had to know that more than they do now because that was more of a survival instinct or knewledg-, basic knowledge that they had to have.
These thoughts were echoed by Participant C when he said,

> A lot of the things that they did back then, you know, they, they did it because they, I, I would say that they made the traditions so that, you know, that the next generation would know what to do to survive.

**Society.** The second category relates to what Maslow (1943) defined as the love needs. Making at this level is first understood in terms of its ability to bring people together. When Participant G was asked what motivated him to learn how to do electrical work, he said, “Just trying to find a, a better job that pays better and keeps me close to my family, like, that my family motivates me.” Participant E mentioned that one form of making that she does is through acting and making videos. For Participant E, her acting is motivated by the opportunity to provide a positive experience for others:

> I have little kids that are fans and they come up to me and they're just so cute. And you know, I'm like, I try to like give them the most positive, you know, interaction that I can you know. I give them hugs, and I always say thank you and stuff like that. And it’s a, it’s just, um, very gratifying. It’s satisfying and awesome. That’s why I make.

Many participants also expressed the importance of making as a way to communicate ideas with others. For example, observing family members while they were making seemed to be a common way of how the participants learned to make. When Participant N was asked how she learned how to make things, she responded:

> My dad, he’s the, I guess he, I would say he’s the artist. So, watching him create new things was something, something new and interesting so that got me my interest, interested in like things like drawing and painting and stuff like that. So, I like doing like artsy things, but I guess [indecipherable] learning from my parents is how I learned how to do certain things.

Making is not only understood as a vehicle to communicate to others in the current time, but to future generations as well. Participant G described how rug weaving is used on the Navajo Nation to communicate history to future generations:
And just like with the rug, that could be like a map of time, like what they did in the past. Because usually when my grandma would make rugs there was no vehicles. It was just, um, cows, horses so it could be just like a place of time that she made that rug for. But now, now that she’s older she’s starting to add more vehicles to it. [laugh]

Participant Y also explained how making has helped important knowledge of how to make things to be communicated from generation to generation:

I mean ever since we were little girls my mother would show us how to make bread and she would keep that going every day. And now I’m a mother and now I’m teaching my daughter how to make bread, so it’s, like, ah, repetitive through generation and that’s just one of the many examples that we were taught was how to cook so now we cook and our children are learning how to cook.

Finally, in addition to these traditional methods of teaching the next generation how to make, some members from the community have also started to incorporate more modern methods. For example, Participant U has seen videos on YouTube regarding “how to make a loom.” Participant U explained that the internet has been his primary way of learning how to make things:

YouTube is a very awesome resource. Like, um, two years ago, he asked, like, how do you change, how do you change your brake pads? It’s like I don’t know. But a friend, um, she helped me, together we both YouTubed it and we changed my rotors, my brake pads, and my calipers. We know nothing about mechanics but that’s how I learned. So, like I just Google how to make a floating shelf, you know, how to, how to make bread, how to make an arch, how to, that’s the way, learn how to do all my making, I guess.

Pride. The next category, pride, corresponds to what Maslow (1943) referred to as esteem needs. Participants at this level described how making something generated a sense of pride within themselves. When Participant G was asked what it meant to him when he made something, he responded, “It just feels great, I mean just, that I accomplished it. Yeah. And it’s just like all that hard work that you put into it, it feels great that it’s actually working. . . . there’s a big sense of pride. [laugh]” In Participant
M’s case, her sense of pride motivates her to make the things that she needs, rather than buy them. She explained, “If I need something I usually, I usually don’t like to buy stuff that I can make.” She then went on to say, “Because to me my products are like the best, you know? [laugh] And if I make something I’m the best at it.”

Several participants expressed that their pride also influenced how they make things. For some, they saw the artifacts that they made as an extension of themselves. Participant E explained,

> There's a lot of love and a lot of care there and I can, I can't, I can't let it be less than, you know, because it's a part of me that I really, I really care deeply for it. And so, I have to, I ha-, I must, it must be the best.

Participant W also expressed a similar perspective:

> I go above and beyond because it has my name on it and I want it to last. I want it to last. I want it to be durable and I want it to, um, [indecipherable], it, it's a piece of me and I w-, I want it t-, to represent my workmanship and I want it to be good.

For some, taking pride in one's work meant paying attention to even the smallest details. Participant W stressed the importance of these details when he said, “I want it to be like I pay attention to detail. I make the like just the little stuff stand out. Because little, the little stuff does matter. Like in everything you do.” In a similar way, Participant M described how her father’s pride in his work affected his approach to jewelry making:

> And then my dad, he, he makes jewelry too, like he used to do a lot of silversmithing. And his jewelry, he used to really take time in his designs and make sure everything was precise and make sure that, um, every, all, like that everything looked perfectly, you know, organized, straight and he, he made some really beautiful pieces of work when he did his jewelry. So, and he took a lot of, um, pride in it, you know, time.

The last theme relevant to this category is the concept of intentional flaws. Despite wanting to make artifacts to the best of her ability, Participant E noted that the reality is, “there’s bad in everything.” As a way of recognizing this, she said, “If I made it
perfectly I would probably put a flaw in there. . . . I was taught that nothing is ever really perfect. And you should always account for that.”

**Self-actualization.** Participants who described making in this next category of self-actualization gave examples of how making allows them to reach their full potential. For Participant C, “When somebody says making that’s, that’s basically what I think of. It’s something to build, to, to, to make your life better.” Participant B gave a similar description of the word making by saying it provided “something to help you accomplish a goal or put steps in front of you to get to some-, somewhere that you want to be.”

Several participants expressed that making helps them satisfy their curiosity and desire to learn. Participant M explained, “The reason why I’m weaving is because it’s like I have a, a passion or a yearning to learn.” Participants who described this category make in order to learn and grow rather than learn in order to know how to make. Making drives these participants into reaching their potential by challenging themselves. For Participant Y, making “makes me, um, want to do more things. I want to build more things because I know that I can accomplish that, making something and then I know I can make something better.”

Making can also help individuals toward self-actualization by creating opportunities for them. Participant E talked about how music has opened doors for her, “So I can read and, and write music. And so I created a, a scale using my, um, Native American flutes. . . . It’s taken me places.” If opportunities do not present themselves, Participant T explained that it is important to make your own opportunities:

I always tell people you’ve got to take the initiative, you’ve got to take the [indecipherable]. You can’t, you can’t wait for things to happen. If someone says I need a volunteer, be the first one to raise your hand. Because you’ll never know where it’s going to take you.
Transcendence. Transcendence is the deepest category of making in the hierarchy. Participants often described making in this category not in terms of what they make, but in terms of who they make. When Participant N was asked if she considered herself a maker she said, “In a way, because I have to make my child a better person [laugh] to make her ready for the world.” Participant T spoke about how proud he was to be the first in his family to receive a college education and go into the technology field because he hoped that his example would help to inspire his nieces and nephews to do the same. In his own words, “So that would probably have to be my, my proudest moment, my proudest achievement, my, what I’m proud of creating, making, is, is, uh, I guess you could say a path.” Perhaps the best example of making motivated by transcendence was provided by Participant E:

My náli [paternal grandmother], um, she said that the most important thing for a Navajo person was to continue themselves. And she like, saying that in Navajo like it’s kind of, you kind of have to interpret that for yourself. And the way to understand it is, you know, you have Navajo children. You teach them a Navajo way of life. And you teach them to be Navajo and speak Navajo. And you create that and you continue it, you know, for generations to come. And so that, as a, as a maker that is one of the most important things that I think of, you know, creating Navajo beings who are, you know, very knowledgeable, very, very, very grounded and you know, intelligent and resourceful. That make, making that, you know, creating that would be a lifetime achievement. [laugh] So that, that includes everything, you know, the weaving, any jewelry making, any, any songs, and even how to pray, you know, that is a, a great [indecipherable] incredible, um, talent.

Spirituality. The final category, spirituality, was one that came up with many participants as they were describing making. After introducing herself at the start of the interview in traditional Diné fashion by naming her four clans, Participant E explained:

All four are represented that way and that all together makes me a person, like, um, um, it’s like a human being, um, like a five-fingered person, like we live in a [indecipherable] sacred space and so that’s, that’s my identifier as I walk, um, like I’m, I’m a, I’m a sacred being.
Not only was spirituality important in how some of the Diné identified themselves, it was also important in the context of making, affecting how, when, and why things are made. This category did not appear to be a part of the hierarchy, but rather, it appeared to be an overarching category that could be connected to any other category. For example, Participant Y gave a description of making a fire that could easily be placed in the survival category. However, she also went on to acknowledge the spiritual element of making a fire by saying the following:

As a Navajo, making a fire, that’s very sacred. And understanding the respect for the fire and what it does for you and what you can do for it. I mean, everything’s a living thing to us as Navajos and fire is one of them.

Similarly, Participant M described how objects can serve one purpose but also have special attributes that may serve another purpose:

Like when you, when you’re making something or designing something you put pure thought into what you need and the purpose it’s going to serve. And sometimes it’s not just basic, um, like a tool or a wrench, it’s, um, some things have, um, thought as maybe protection or, um, some things can be sentimental. Some things can be, um, like mer-, remind you of something. Some things can have, um, special values that, um, relate to certain, maybe parts of, in your life, you know, that it becomes more, more than just a small item, you know, or just, just an object.

Several participants expressed the importance of maintaining positive thoughts while making. Participant Y explained that “the process of thinking as, as a Navajo it’s, um, it’s sacred. What you think it’s kind of like putting it out there in the universe. S-, you’re already thinking it so, it’s going to happen.” Participant W mentioned that this positive thinking was necessary for him to be able to make:

When I’m making stuff I can’t get into the mode unless I’m, I guess I’m in positive thoughts. . . . Like when I was in the body shop and you know, wasn’t feeling that, wasn’t feeling too good, I, I would think no matter how many times I di-, did it, you know, it just wouldn’t come out right. So, if I just got away and went away from it for a while and then came back to it then everything would work out right.
Participant Y talked about how technology can often lead to negative thoughts and why it was important for her to try to avoid contact with it while she was making:

I do believe that in having a positive thought but sometimes you just can’t help the negativity and there’s so much going on, especially with now there’s media everywhere and it’s, it’s always going with technology so, I mean, even if you try to be alone you have to kind of void out everything, all of technology to kind of keep yourself in that positive main, mind frame. But if you have your phone and you’re trying to do something and something, a message or Facebook or something pops up and it’s negative, then that ruins your whole negative thoughts and then you start thinking about that while you’re making something so it’s kind of good to kind of exclude yourself from technology when you are trying to make something good.

Participant M went even further and explained how someone’s frame of mind when they make an artifact can affect other people who interact with that item:

So, like for Native Americans, making all that kind of stuff you have to be positive. Even cooking, like when you’re cooking fry bread or making whatever. My, one of my, my great, or my grandfathers, he passed away, um, he used to say, he used to always say when you cook make sure you’re in a good mood because when people eat your food, the mood that you have is how they feel. So, you have to kind of always be happy and be positive when you’re cooking, especially for other people, you know, because it’s like what they eat is what you put out and if you want everybody to enjoy your food and be happy then you have to be positive when you’re cooking, you know.

Finally, Participant M gave an example of how making, in this case weaving, can be a reflection on your life:

How you manage your, the problems you, you have is how your weaving shows it. But at the same time, with your weaving, if you’re, like when you’re patient and you’re trying to like figure out what’s really, what, what’s happening, it seems like in the end you start having more patience in your life. So, like for me when I started weaving every time, every time I heard the stomping of the, the, I mean it was like a comb. You stomp do-, you stomp down the, every time you put a layer of, of yarn there you stomp it down and it, it stabilizes it. It seemed like everything I did had that sound or that same action. So, when I was sweeping or cleaning or doing something it, it seemed like it resembled weaving and then when I was driving I noticed the layers of earth. I noticed the layers, you know, different colors of nature and it seemed to tie into, to weaving. It seemed
like weaving was this big secret that, you know, a world or a life secret that nobody knows. It’s like only I had it now. You know? And that, so that kind of, when I told my instructor she said, maybe you’re, you’re blessed.

A summary of the six categories that emerged in this study is provided in Table 4-1.

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survival</td>
<td>Recognizes that making can be used to aid the survival of people</td>
</tr>
<tr>
<td>Society</td>
<td>Describes making as a social act to communicate ideas and build relationships</td>
</tr>
<tr>
<td>Pride</td>
<td>Acknowledges that making instills people with a sense of pride</td>
</tr>
<tr>
<td>Self-actualization</td>
<td>Describes how making helps people fully realize themselves</td>
</tr>
<tr>
<td>Transcendence</td>
<td>Understands that making benefits a person’s community and future generations</td>
</tr>
<tr>
<td>Spirituality</td>
<td>Views making as a spiritual act</td>
</tr>
</tbody>
</table>

4.1.2 Relationships Among Categories

During the data analysis process, I determined each category of making that the participants expressed in their interviews. The results of this portion of the analysis is summarized in Table 4-2. Just as in Maslow’s hierarchy, where it was generally not possible to address higher-level needs until all lower-level needs were satisfied, participants did not describe the deeper and more meaningful understandings of making unless they were also aware of the more superficial ones. It should be emphasized that spirituality in the context of making appeared as an overarching category and could be said to exist around the hierarchy rather than within it.

In general, the data supported the hierarchy that was found in this study with two notable exceptions. In the first exception, Participant D described an understanding of how making could help someone towards self-actualization without expressing any of the themes found in the pride category. To be respectful of the participant’s busy schedule, this interview was the shortest one conducted in the study. It was also
conducted at the end of the data collection process, so it was not possible to schedule the interview for another day when the participant would have more time. I decided it was better to have a brief interview than none at all. The condensed nature of the interview may have prevented the participant from being able to fully describe his understanding of making.

Table 4-2. Spectrum of participant understanding of the experience of making

<table>
<thead>
<tr>
<th>Category</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
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<th>H</th>
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<th>T</th>
<th>U</th>
<th>V</th>
<th>W</th>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survival</td>
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<tr>
<td>Society</td>
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<tr>
<td>Pride</td>
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<tr>
<td>Self-actualization</td>
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<tr>
<td>Transcendence</td>
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<tr>
<td>Spirituality</td>
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The second exception is that Participant X also demonstrated an understanding of the deeper forms of making without providing an example that would fit in the pride category. One possible explanation is that this interview was the first one conducted in the study. Based on the outcome from this initial interview, several adjustments were made to the protocol regarding how some questions were asked, affecting how the participant may have responded.

Another way of displaying the data is shown in Table 4-3. In this table, all participants were plotted horizontally on the deepest category of making that they expressed in their interviews. Additionally, they were also plotted in the vertical direction depending on whether or not they acknowledged the spiritual component of making. Viewed in this way, it is shown that each of the hierarchical categories contained at least one participant, which implies that each category is unique and necessary to fully describe the participants' understanding of making. Interestingly, it appears that the
participants did not express the spirituality category unless they also expressed the deeper categories starting with pride. While it is possible that this outcome might simply be an artifact of the study’s small sample size, it may warrant further investigation.

Table 4-3. Deepest category of making expressed by the participants

<table>
<thead>
<tr>
<th>Spirituality?</th>
<th>Survival</th>
<th>Society</th>
<th>Pride</th>
<th>Self-actualization</th>
<th>Transcendence</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>H</td>
<td>L, R, S</td>
<td>D, J, U</td>
<td>N, T, V, X</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>W</td>
<td>B, G, M</td>
<td></td>
<td>C, E, Y</td>
<td></td>
</tr>
</tbody>
</table>

4.2 Discussion

4.2.1 Implications of Findings

The outcome space of this study begins to illuminate the ways that the experience of making is understood on the Navajo Nation. Some of the ways that participants described making aligned well with how it is understood in Western culture, while others seem to be unique to the Diné people. The findings discussed in this section should be used to help inform new programs and curricula that look to leverage making to encourage students from the Navajo Nation to become interested in pursuing a career in engineering. This section also discusses the implications that the findings of this study have for Maslow’s theory of human motivation.

While I have not encountered any literature that has attempted to describe the variations of how making is understood in a hierarchical fashion, many of the categories of description that emerged from the data resonate with the findings of previous studies. In the society category, it was mentioned that making can be a source of communication, just like how the artifacts that visitors leave behind in the Children’s Museum of Pittsburgh’s Makeshop help to communicate ideas to the next group of makers that come to use the space (Sheridan et al., 2014). The Diné people’s practice of introducing intentional flaws while making was also noted in the literature by Benally
Finally, Sivek (2011) provided evidence of self-actualization and transcendence in *Make: magazine*.

The results of this study suggest several adjustments to Maslow’s framework when being used within the context of the Navajo Nation. The first proposed adjustment is to eliminate the safety category. The participants’ descriptions gave no evidence of this category of human motivation. A similar simplification to Maslow’s framework was also argued for in a study by Mathes (1981). Participant E’s account of how she considered transcendence to be the most important hierarchical category reflects the findings of Red Horse (1997). Accounts like hers led me to recommend a second modification to the framework by inverting the pyramid in the model of the outcome space. The findings of this study also suggest an additional category to be considered in Maslow’s framework: spirituality.

While Maslow (1943) was very careful not to claim that his theory is absolute, I feel that he undervalued the role that one’s cultural upbringing may have on their behavior. One of the first things that Participant E did in her interview was to identify herself as “a sacred being.” Maslow’s original hierarchy is not able to explain the motivation behind practices like why the Diné build hogans, traditional Diné dwellings, so that their entrances face east. The concept of spirituality is a powerful force for several participants that not only affects how they make something, but also why they make it. I believe that the findings are evidence that Maslow’s framework is even less universal than he believed. While it is true that people across many cultures may share commonalities, it is overly simplistic and incorrect to assume that any differences are entirely superficial in nature.
In addition to having implications for Maslow’s framework, the concept of spirituality also played a significant role in making based on the responses from several participants. For example, thoughts were described as being sacred and having an impact during the making process. If a maker has positive feelings while making an artifact, then those same positive feelings will be transferred to anyone who goes on to use the same artifact. One participant went even further to say that these positive thoughts were required for him to be able to make. The role of positive thinking while making was not a concept that I had encountered in the literature before, nor was the role that spirituality plays in making. While it is beyond the scope of this project to fully explore what role spirituality plays in the Diné understanding of making, it would be very important for engineering educators to work with community members to ensure that any making programs or curriculum developed for Diné students acknowledged the role of spirituality in a respectful and culturally appropriate manner.

Last, Participant E’s powerful description of what she believed was the greatest form of making has implications for engineering educators. Her comments suggest that any program involving making for the community should shift the emphasis away from what is made to who is made. For example, many Western makerspaces will display various artifacts that have been produced in the space. They serve as an inspiration to future makers as well as provide examples of what is possible to make using the space’s equipment. A makerspace on the Navajo Nation might shift this attention to the users of the makerspace. Instead of displaying artifacts, a Navajo Nation makerspace could showcase photos or short video biographies of people who have used the space.
4.2.2 Reevaluating the Model

After developing the model for the outcome space described in this chapter, I presented it to the Navajo Nation community to receive their feedback. Two Diné qualitative researchers asked critical questions about the design of the model. In particular, one researcher believed that I may have misinterpreted what the elders meant by turning Maslow’s hierarchy upside down in Red Horse’s (1997) study. This particular researcher thought it might be better to leave the pyramid upright but change the order of the categories so that transcendence would form the base of the upright pyramid.

These Diné researchers also saw the model as a reflection of the current state of NTU. Universities are inherently Western institutions. Thus, NTU is a Western academic institution situated within the context of a community with an entirely different worldview. In the same way, the center of the model features a linear hierarchy inspired by Western thinking surrounded by the circular traditional Diné understanding of spirituality. The participant pool included a mix of those who could be considered traditional Diné, Westernized, and many who fell somewhere in between. The inherent contradiction of this model reflects the internal struggle that many of the participants, as well as NTU, face in trying to balance living in two worlds.

The same researchers recommended that there should be an opening at the top of the circle to emphasize that nothing was perfect. They mentioned that this imperfection could be viewed as an entrance. By orienting the model so that this

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I would like to acknowledge Kelsey Dayle John and Dr. Tim Begaye for providing this valuable insight on the model developed in this study.
entrance is aligned with the eastern direction, it then reflects the top-down view of a hogan. After this realization, the researcher who was originally concerned about the orientation of the pyramid suggested that perhaps it should stay inverted. Traditionally, the medicine man sits on the western side of the hogan facing the entrance. Doing so would put the medicine man’s seat at the tip of the pyramid, reinforcing that he is a holder of knowledge. While I did not intend to design the model in a way that reflected the layout of a hogan nor the struggle that many of the Diné people face by living in two worlds, the Diné researchers believed that it was not an accident that it came through in the design of the model.

4.2.3 Study Limitations

It is important to emphasize that the findings in this study are highly contextualized. These findings represent the variation in understandings of only the people who participated in this study at the time that they were interviewed. It is not appropriate to generalize these findings to other Native American communities nor to the Navajo Nation as a whole. Nearly all of the participants in this study were students at a university who have perspectives on making that may not adequately represent the rest of the Navajo Nation. As a result, the resultant outcome space generated from this study is merely a portion of the overall outcome space that describes the variation in ways in which the Diné understand the experience of making.

The next limitation derives from who conducted this study; a noncommunity member from an external institution. While I was analyzing the data, it became apparent that the spirituality category is directly tied to the traditional Diné culture. I fully acknowledge that even having worked with the community for over 7 years, at best I have a limited understanding of the culture, which made it impossible for me to fully
explore the spirituality category without running the risk of a potential misinterpretation. While there is much more to learn about how spirituality is entwined in the Diné understanding of making, I believe that it must come from a study designed and implemented from within the Navajo Nation.

The lack of someone from the Navajo Nation on the research team also limited how the research project was designed. For example, rather than using phenomenography to analyze the data, perhaps a methodology developed by the community would have been more appropriate. Additionally, as mentioned in Section 3.9, my prior understandings of making affected the types of questions I included in the protocol. It was almost in spite of the protocol design that some of the deeper levels of making emerged. Perhaps a researcher from the Navajo Nation would have asked different questions that may have led to a more complete understanding of the outcome space.

Finally, because it was the first time a study like this was conducted in the Navajo Nation, it was not clear what was to be expected. As a result, the design of the study had to be flexible, which led to modifications of the first research question as well as the methodology. Modifying the first research question, as mentioned in Section 3.6.5, created an attrition of data that affected which portion of the outcome space was revealed.

4.3 Summary

The goal of this chapter was to address the modified first research question: In what ways do the Navajo describe the experience of making? Implicit to this question is another question: Why do the Navajo make? This question was addressed by determining the outcome space of how the Diné describe the experience of making
using phenomenography and Maslow’s hierarchy of needs framework. The resultant outcome space consisted of five hierarchical categories that represent the unique ways in which the participants described the experience of making: survival, society, pride, self-actualization, and transcendence. One overarching category that has no equivalent in Maslow’s framework, spirituality, also emerged during the data analysis. The sum of these categories and the description of the relationships between them form the outcome space, the product of a phenomenographic research project. This understanding of the Diné people’s motivations for making may benefit those who seek to address the underrepresentation of Native Americans in the engineering field by developing programs that promote interest in engineering careers for the Navajo Nation through making. In particular, people developing these programs should keep in mind that making for the Diné people may be considered a spiritual act, a maker’s thoughts play an important role in the process of making, and who is being made should be valued over what is being made.
CHAPTER 5
SECOND RESEARCH QUESTION METHODOLOGY

In this chapter, I discuss the implemented research design for the second research question. While the nature of this question required a methodology other than phenomenography, the other components of the research design remained the same. For more information regarding the chosen epistemology, theoretical perspective, and research methods, refer to Sections 3.2, 3.3, and 3.6 respectively. This chapter instead focuses on the methodology chosen to address the second research question: the engineering design process. The goal of this chapter is not to summarize the wide variety of understandings of this process, but rather to make explicit my own interpretation of the engineering design process and how it fits within the context of this study. The chapter concludes with a short summary.

5.1 Modification to the Second Research Question

When viewing the second research question, How can Navajo and Maker culture be integrated in order to design a culturally-contextualized makerspace? from the same critical lens as I viewed the first question, a concern was raised. One of the objectives of this study was to create several preliminary designs for a culturally-contextualized makerspace for the Navajo Nation. Trying to incorporate the Western understanding of making into the design of a Diné makerspace is both inappropriate and detrimental towards the obtainment of this goal. As a result, the incorporation of Western making was removed, and the second research question was rephrased as follows: How can the Navajo experience of making be integrated to design a culturally-contextualized makerspace? These changes were made so the research questions would remain consistent with the study’s theoretical perspective.
5.2 Engineering Design Process

While phenomenography was an appropriate methodology for addressing the first research question, it was not suited for the task of synthesizing the data from the transcripts into designs for the culturally-contextualized makerspace. Instead, the engineering design process was the methodology chosen for answering the modified second research question. For this study, I chose to use the steps of the engineering design process as defined by Shigley and Mischke (2001): recognition of need, definition of problem, synthesis, analysis and optimization, evaluation, and presentation. Because this project was only concerned with developing the designs for the culturally-contextualized makerspace, only the first four steps of the process were considered while the rest were left for future work.

5.2.1 Recognition of Need

The first step in the engineering design process is to identify or recognize a need. In this project, I recognized the need for a culturally-contextualized makerspace that can be used to promote interest in and exposure to engineering careers on the Navajo Nation. Crane (2014a) stressed that in this first step in the process, it is critical to define the need in as general of terms as possible. Doing so prevents any potentially viable solutions from being eliminated at the very start. For example, one can imagine that the recognition of the need in this project was phrased as follows: “There are no known examples of how a room in a library can be redesigned into a culturally-contextualized makerspace used to promote engineering concepts to a Native American community.” This statement, just in the way it is phrased, makes several assumptions that artificially constrain the project. What if a library is not the most appropriate place to put the makerspace? What if the makerspace is not even in a room? Perhaps a mobile
makerspace would better suit the needs of the community. The goal for this step is to adequately define the need without placing any unnecessary constraints on the project.

5.2.2 Definition of Problem

Defining the problem is the next step in the process, where a list of all the requirements and constraints of what needs to be designed are generated. While it was important for the identification of need to be very general, according to Crane (2014a), the specifications on this list need to be phrased so there is no room for ambiguity, for they will ultimately be used as the criteria under which the design will be judged.

Dym et al. (2005) recommended that to remove ambiguity in the design specifications, the designer should ask questions. For example, suppose a community member provides a specification that says, “the makerspace must be able to fit in a small room.” The designer should immediately be asking, “Exactly how ‘small’ is a ‘small room?’” This question may lead the community member to rephrase the specification: “The makerspace must be able to fit into a rectangular room with the dimensions of 10 feet x 15 feet and a height of 10 feet.” This statement removes any ambiguity, allowing designers to objectively check if their proposed designs will meet this specification. It is important to note that while a design must objectively meet all of the design specifications, this does not suggest the existence of one ideal design. Just as constructionism allows for the possibility for multiple truths, the engineering design process allows for the possibility of multiple designs that meet all the requirements and fit within all of the constraints.

How these specifications are generated varies depending on the project. Shigley and Mischke (2001) noted that they may come “from the designer’s particular environment or from the nature of the problem itself” (p. 15), but in general, they are
given to the designer by a customer. From a critical perspective, it is important that these specifications are derived from the community directly. During the interviews, participants were asked questions such as, “What do you think a Diné makerspace would look like?” Using their responses, as well as the findings from the modified first research question, I derived a list of specifications that guided the design of the makerspace.

The first step in deriving the design specifications was becoming familiar with the transcripts. Next, I went through each transcript and identified each utterance by a participant that addressed the modified second research question. These quotes were then sorted into categories. For example, quotes regarding what types of tools should be present in the makerspace were sorted into the “Equipment” category. In some cases, quotes were sorted into multiple categories. The quotes from these categories were then condensed into the design specifications. Additionally, some of the specifications were informed by the findings of Chapter 4.

5.2.3 Synthesis

Once the problem has been properly defined, the designer can start synthesizing design concepts. How designers choose to generate these concepts depends on their preferences. Some of these methods include adaptation, analogy, area thinking, involvement, brainstorming, and functional synthesis (Crane, 2014b). Each of the design concepts in this study was generated using a different method. The first design was provided directly by one of the participants. The second makerspace concept was derived using adaptation. Crane (2014b) described adaptation as occurring when the “solution of a problem in one field is applied to a similar problem in another field.” The
final concept presented in this study was generated by incorporating aspects of the first two concepts to form a hybrid third design.

5.2.4 Analysis and Optimization

Shigley and Mischke (2001) explained that analysis and optimization are closely tied to the previous step, synthesis. While designers are generating concepts, it is important that they develop prototypes and analyze their performance to determine their viability as concepts. Based on the feedback from these analyses, these concepts are improved upon and analyzed again. After several iterations, designers will choose the concept that they believe will best address the identified need and problem definition. In this study, computer-aided design, or CAD, renders of the different initial design concepts were generated and then presented to community members. Based on their feedback, these concepts were refined.

5.3 Summary

The second research question required a modification from its original form. The engineering design process, as defined by Shigley and Mischke (2001), was chosen as the most appropriate methodology for addressing this modified research question. In Chapter 3, explicit examples were provided regarding how each of the research design elements complemented the others. With a new research question and methodology, it is important to once again evaluate the relationships among each of these elements and provide examples of how they are in harmony with the others. A summary of this evaluation can be found in Table 5-1.
Table 5-1. Justification of consistency in the research design of the second research question

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CHAPTER 6
FINDINGS OF THE SECOND RESEARCH QUESTION

This chapter discusses the findings of the modified second research question:

*How can the Navajo experience of making be integrated to design a culturally-contextualized makerspace?*

6.1 Recognition of Need

The recognition of need for this project was formally stated as follows: There is a need for a culturally-contextualized makerspace to help promote interest in and exposure to engineering careers on the Navajo Nation.

6.2 Definition of Problem

The data analysis method described in Section 5.2.2 produced the following design specifications for the Diné makerspace:

1. **The makerspace must be a physical place.** Participants who described the first design specification did so by referring to the makerspace in terms of a building or a physical place. For example Participant R mentioned,

   "You would actually need a garage because you couldn't do it outside. You need a confined place with a roof. Um, I'd say anybody could be a maker as long as they have some type of building and the right type of tools for whatever they wanted to make."

   Participant C went even further to describe the makerspace as a safe place where the youth in the community could work towards something positive:

   "I think that it would, you know, [indecipherable] definitely help a lot of kids that, that are out there that, that want to belong someplace. It will help them, you know, find a place to belong and to actually get involved in, in, in making and get, eventually get into engineering or, you know, [indecipherable] finding something that they're good at."
2. The projects conducted in the makerspace must be hands-on.

Participants also expressed the importance of facilitating hands-on learning within the makerspace. For example, Participant Y said,

I mean, Navajo people, well most people, but they, they did a study and they said Navajo, Native Americans are mostly hands-on people, that's how they learn. . . . I mean, that's just, that's just our nature it's, and I never knew that until that study came out and then like, yeah, w-, we are hands-on.

3. The makerspace must have a place where makers can store personal tools. The topic of sharing tools was a touchy issue for some participants. Participant Y had the following to say about it:

So sharing, it's okay if you both understand each other, but if you have an individual that doesn't put things back where they should be, then yeah, it would be a problem because then you'd both start getting frustrated and then that's where your negative thoughts come in.

Participant W explained that he preferred to use his own tools over the ones that were provided at NTU’s Fabrication Lab by saying, “If I had my own choice I would use my own tools because then I know how hard I can go, I can push it. And if I break it then it's my own fault.” To him, tools were seen as a source of one's income. He seemed hesitant at the thought of borrowing someone’s tools because he understood the responsibility that came along with that. He went on to say,

I think a makerspace would be good if you could have your own little corner to where you can have your own toolbox. To where you can lock it down and, you know, get in there and use the space and use your own tools and, and you know, you can keep it clean, put away all your stuff, put away all your tools and, and you don’t have to worry about people coming and taking things.

To address the participants’ concerns, the space should have a place where individuals can store their own tools in addition to having tools that are available to everyone who works in the makerspace.
4. **Makers should have the ability to learn through observation.** The makerspace should also facilitate its makers’ ability to learn through observation. In Participant Y’s own words,

Because me, myself, I watch people do things and then I’d imitate it and then when it came my turn to do it I could do it. And a lot of my relatives are like that. I have people that could weld and build buildings from watching other people and the only thing that’s keeping them is they’re not certified. But their building is still standing compared to somebody who is certified.

One way to help facilitate learning through observation would be to have computers with access to websites like YouTube. However, that alone would not be sufficient. When Participant W was asked, “Would you rather watch a video on YouTube about how to do something or learn from somebody in person?” he responded,

I would say learn from somebody in person, somebody that’s kind of got the experience and somebody that knows what’s going on and they, they’ll be, they’ll be better to, to teach you about it than to, than to try to improvise what, what you’re watching.

Guest instructors could provide classes where makers could learn from observing masters at a specific skill.

5. **The makerspace must have a facilitator who can assist makers.** During the everyday operation of the space, facilitators could help makers become familiar with all of the equipment and be available to answer their questions. According to Participant E, there would need to be someone to,

Introduce them to all the stations. Um, and just, just basically say here they are. This is what it’s for. Um, you’re free to use it at any time. If you need help just, you know, help, I’ll, I’ll, I’ll help you.

6. **Makers should be able to choose which projects they wish to work on.** Several participants also expressed that it was important for makers to have the ability to choose projects that are meaningful to them. Participant V explained,
I would say like have like, projects, like give them ideas, or I mean if they don't know, like if they're new to it, then just have projects available that they can become familiar with how to use certain equipment or help them understand like ho-, how like the process of making things. But also have like the ability of others to create what they want.

Allowing makers the ability to choose between readily available projects and those that they can create on their own addresses the full spectrum of needs that might exist in a makerspace. New makers may not know where to start, so projects readily available that help them become familiar with the tools and resources in the space will provide them with needed initial structure. Once they feel comfortable working in the space, the freedom to choose their own project will ensure that they are working on something meaningful to them.

7. **The makerspace should be environmentally friendly.** In Chapter 4, it was revealed that a scarcity of resources has helped the Navajo Nation to foster a respect for available resources and to waste nothing. Therefore, it is also important that any design of the makerspace should utilize materials that help to limit waste. Participant U also commented that the makerspace should “be LEED-certified. Um, have more, even give more power to the grids. Have solar panels everywhere. Heat the buildings with sunlight.” With regards to the types of things that would be made in the makerspace, Participant T stated, “Well, first thing that comes to mind is, uh, renewable energy, so, wind turbines, solar cells. Um, uh. What do they call these water, water capture devices. Things like that.”

8. **The makerspace should focus on celebrating who is made there, not what is made.** The emphasis on celebrating the makers over the things that they make was another finding that was discovered in Chapter 4. Participant E explained,
You have Navajo children. You teach them a Navajo way of life. And you teach them to be Navajo and speak Navajo. And you create that and you continue it, you know, for generations to come. And so that, as a, as a maker that is one of the most important things that I think of, you know, creating Navajo beings who are, you know, very knowledgeable, very, very, very grounded and you know, intelligent and resourceful.

To Participant E, helping to nurture and develop the next generation of the Diné is the greatest form of making, and it is important that a Diné makerspace reflect this understanding.

9 & 10. The makerspace should be located somewhere that maximizes how many people from the Navajo Nation have access to it. People in remote areas of the Navajo Nation should have access to the makerspace. The last two design specifications represent a trade-off. Establishing the makerspace in a central location would help to ensure access to as many people in the community as possible. However, doing so would also potentially prevent members from the more remote areas of the Navajo Nation from receiving access. Participant C described this dilemma in the following way:

I would say, you know, since a lot of things are centralized in, you know, the Window Rock area, you know, and, you know, everybody drives basically to Window Rock, too, you know, but they also drive to [small community on the Navajo Nation], too. [laugh] But, you know that's, I'm just saying that just because, you know, I'm from [small community on the Navajo Nation], I grew up there. But it would be nice to see something of that in a, in a smaller place, you know, and so, you know, way out in the middle of nowhere. That, that, that would be cool.

While Participant C understood the rationale for putting the makerspace in a centralized location, coming from a smaller community himself, he felt it necessary to advocate for these smaller communities that may not have as many opportunities. Participant V came up with one potential solution when she said, “I think it would bene-, like it would be beneficial if it was like mobile maybe. That way you can access more areas.”
All ten of the derived design specifications are presented below.

1. The makerspace must be a physical place.
2. The projects conducted in the makerspace must be hands-on.
3. The makerspace must have a place where makers can store personal tools.
4. Makers should have the ability to learn through observation.
5. The makerspace must have a facilitator who can assist makers.
6. Makers should be able to choose which projects they wish to work on.
7. The makerspace should be environmentally friendly.
8. The makerspace should focus on celebrating who is made there, not what is made.
9. The makerspace should be located somewhere that maximizes how many people from the Navajo Nation have access to it.
10. People in remote areas of the Navajo Nation should have access to the makerspace.

**Makerspace Equipment.** When the participants were asked about what types of equipment the makerspace should have, as one might expect, there was a wide variety of responses. However, some equipment that came up more frequently included 3D printers, CNC machines, weaving equipment, silversmith equipment, computers, woodworking tools, and robotics equipment. The types of equipment selected for the makerspace cannot be generalized for the entirety of the Navajo Nation. Instead, the specific Diné community that wishes to build a makerspace would need to come together to determine which tools and machines are most appropriate to meet their needs.

### 6.3 Synthesis

Using the design specifications detailed in the previous section, several design concepts of the makerspace were synthesized. The first design concept was provided
directly by a participant and incorporated the Diné process of internalizing knowledge into the physical layout of the makerspace. The second concept was adapted from the mobile hospital makerspace described by Nelson (2015) while still drawing ideas from the first design. The final design is a culmination of the first two concepts as well as MIT’s makerspace network (MIT Project Manus, 2017). Each design concept is described in detail in the following sections.

6.3.1 Design Concept 1

The first design concept came directly from a participant. While being interviewed, Participant E mentioned that during grade school she used to work in a room that might be described as a makerspace. She was then asked, “If you were to redesign that room and put whatever you think that you would have needed and arranged it in whatever way you thought would have been best, what would that room look like?” She described her design in the following way:

Well, like computers always useful, um, so I don’t know, I, I just feel like, you know, you would really think hard, like you know, about whatever you’re, you’re working on. It might be a paper, it might be a project, um, whatever. So, um, we put the computers over there on the east side. Probably put a like a whole pod of them, like a whole bunch of them that way you know, you can do that. You can start, you can start your, um, you know, your thought process with the computer at any time. And then on the south wall I put some supplies, you know, just like maybe like, um, you know, maybe some coloring, coloring things. Maybe some different kind of craft, craft items. Any kind of like, you know, maybe like string or whatever, you know, like blocks or whatever. I would put all kinds of cool stuff there. Um, uh, basically this would follow the same, the same like train of thought that I would have, um, based on the Navajo cycle. Um, you know, with the east being [speaking in Navajo] where you think and the south being, uh, the planning and that’s where I put my supplies there. And then I would put the west like, like [speaking in Navajo] like with your life. And you know, knowledge is power, life, whatever, library, boom. I love books. And then on the north I would put some really nice comfy chairs because I just think that rest is also important. Um, being able to be at ease and comfortable. Um, especially when, you know, like, you know, you have a, you have a lot on your mind. Maybe you just want to like take
some time to chill and you know, think about it, just relax. So in the middle
definitely lots of work space and um, you can like spread out your poster
and like make it, you know. I think this would be a really awesome room.

The *Navajo cycle* that she referred to was likely the four-stage process of
internalizing knowledge that is part of the Navajo philosophy of learning described by
Benally (1994). Previously in the interview, Participant E gave this description of the
process:

This, um, [speaking in Navajo] is that bright blue time of day, right now.
And the, the tenet of, of that like it’s, it’s the southerly direction that, that
that’s associated with and that is, um, it’s planning, um, [speaking in
Navajo] it’s one of the things that, that Navajo Tech teaches here. Um, it’s
planning so that’s when you would do all of these things. Like you put
these things into action like you collaborate with people and that, this is
the time for it. And then like the westerly direction and the tenet for that is
the [speaking in Navajo] when the sun goes down. Tha-, that, that’s like
the life that you’ve made all day long. You’ve created these life, these
things of life and, um, that’s when you put your yellow corn down and you,
you know, like I said you might’ve had something good happen. And then
like the, the first, the first one, the easterly direction from that, that white,
that’s [speaking in Navajo], and that’s when you, you, you think about it
first, then you do your planning then you do your action. So it’s that sacred
thought in the morning that you pray about and then you put the offering
down then, maybe it will [indecipherable], maybe it will come, maybe it will
become.

She was then asked, “And what about in the north?” She explained,

North is, um, north is the, the, um, the darkness is [speaking in Navajo].
And [indecipherable] it’s really a time of reflection. Um, and that’s, that’s
when, you know, you, you stay in, you stay inside. And then yo-, that’s
when you can, you know, burn your cedar. And you know, you, you
cleanse yourself, you protect yourself, um, a lot of people don’t really, uh,
know about th-, th-, the north, that [indecipherable] that it’s
[indecipherable] it’s a protector. Like in the ceremony we banish things off
to the north but like the [speaking in Navajo], uh, tenet of the north, um,
people say that it’s hope. And it is like hope but it’s not, that’s the,
[indecipherable] one word hope doesn’t even encompass what the whole
thing is. It’s really a protection. Like we banish things off to the north and
this [speaking in Navajo] it protects us, it’s, it, it, it, it’s like, almost like a, a
boundary that the evil things cannot come back across. So I, I, I believe
that’s one of, one, one of the things that’s why you put your things down.
You know, because you stay reverent. You just, you just chill [laugh].
In the design of her makerspace, Participant E adapted this process of internalizing knowledge to a process of making: thinking, planning, acting, and resting and reflecting. Figure 6-1 depicts a rendering based on her design as viewed from the top. Additional renderings of this makerspace design are depicted in Figures 6-2 and 6-3.

In this first design concept, the eastern wall corresponds to the thinking phase of the process described by Participant E. It features several computers to allow makers to research any relevant topics prior to making a project. The southern wall corresponds to planning. This section of the makerspace includes cabinets and shelves full of materials that can be used for projects. Mounted to the wall is a large white board where makers can draw out their ideas before they begin to construct them. Additionally, this wall has a place for makers to leave any unwanted scrap materials they generate. These leftover materials would be available for any maker to use for free and would help the makerspace to reduce the amount of waste it produces.

The western wall is dedicated to acting and features the tools and equipment required for the building and construction phase of the making process. In this case, it has two looms, a 3D printer, a tool chest, and a bookcase full of books related to making. While Participant E mentioned that she believed a library should be located on this side of the room, it may be more appropriate to locate the books on the eastern wall to correspond with the thinking phase of the process. Additionally, while Participant E never explicitly described a place where makers could keep their personal tools, perhaps it would be appropriate to place lockers on the western wall to correspond with the acting phase of the making process.
Figure 6-1. Render of a top-down view of Design Concept 1
Figure 6-2. Render of the eastern and southern walls of Design Concept 1
Figure 6-3. Render of the western and northern walls of Design Concept 1
The western wall is where one's thinking and planning are realized. Participant B mentioned that the western wall in a hogan is also typically where making occurs, which he explained is likely because people working in the western side of the dwelling "can face East and I guess in the morning the sun will come up and it will shine through the door and it's just like receiving blessings and stuff." For this particular implementation of the design, it was assumed that the makerspace would be located in a room within a larger building. In this case, it is likely that there would not be a direct entrance from the outside to the room. In place of a doorway facing east, this design has incorporated large windows on the eastern wall to allow the morning sunlight to enter the makerspace and be visible to those who are working on the western wall.

The northern wall is a place for resting and reflecting. It features a comfortable couch as well as a SMART Board, and would be an area for makers to communicate what they learned with each other as well as to rest before they begin the process all over again. The center of the room features large round tables where makers can work collaboratively or removable dividers can be added to provide individualized space. When an instructor is teaching, two of the tables can be separated and moved to the configuration shown in Figure 6-4, which allows all of the students to be able to view the instructor using the table in the center of the room. This design concept can meet all of the design specifications with the exception of the trade-off between the last two specifications.
Figure 6-4. Render of Design Concept 1 in the teaching configuration
6.3.2 Design Concept 2

The second design concept was derived through the process of adaptation. As mentioned previously, there was an inherent trade-off between balancing the number of people who have access to the makerspace and making sure that the residents of more remote communities also have access to it. The inability of these remote communities to access a centrally located makerspace was similar to the problem described by Nelson (2015), where children at a hospital were unable to leave their rooms to visit a makerspace. In the case of the hospital patients, their inability was caused by a lack of mobility, while the residents of these remote communities on the Navajo Nation would be unable to reach a centrally located makerspace due to long traveling distances. Similar to the hospital makerspace, the second concept was designed to be a mobile makerspace that could be transported around the Navajo Nation. One simple solution would be a tool chest that could fit into the bed of a pickup truck. Building from the first design concept, each drawer is dedicated to a different step in the process of internalizing knowledge for the Diné people. Figure 6-5 shows what this design might look like as well as what types of materials would be held inside of it.

The top drawer is dedicated to the eastern direction and would contain items to assist makers in the thinking phase. While it is not possible to fit in the desktop computers that were part of the first design concept, this drawer could house tablets or laptops along with their chargers. The drawer below would feature materials to help makers with planning projects. It would include items like paper, pencils, markers, stencils, and rulers. This drawer would also house construction materials to be used in projects. However, due to inadequate space, projects produced using this makerspace would be limited to materials that would not require using larger equipment like power
tools, laser cutters, and 3D printers. Rather than constructing projects using wood and metal, this makerspace would focus on those constructed from materials like cardboard, string, fabric, and tape. This drawer would also include wires, solder, electrical tape, and microprocessors that makers could use to augment their projects.

The third drawer from the top corresponds to the acting phase of making and would primarily feature tools used for constructing projects, which would complement the materials found in the second drawer such as a soldering iron, scissors, a hot glue gun, wire strippers, and a sewing kit. The bottom drawer is dedicated to the last step in the making process, resting and reflecting. Because it is not possible to fit a couch inside a tool chest drawer, comfortable seating would have to be provided by the host community. Instead, this drawer is used to house a projector that could be placed on top of the tool chest. This projector, along with the tablets or laptops from the top drawer, would allow makers to communicate what they learned while they engaged in the making process. Notebooks would also be kept in this drawer to allow makers to document their projects.

While the tool chest itself does not meet the design specification of being a physical space, it was assumed that whichever community hosted the makerspace would provide a suitable temporary location. Whether or not the other design specifications are met would be dependent on the implementation of each community that utilized the makerspace. The true advantage of this design is that it could potentially satisfy the last two design specifications simultaneously by being accessible to the remote communities of the Navajo Nation as well as those with larger populations.
Figure 6-5. Render of Design Concept 2
6.3.3 Design Concept 3

The final design concept combined ideas from the first two concepts. Rather than consisting of a singular makerspace, this design was generated to address the design specifications by creating a network of makerspaces. Remote communities on the Navajo Nation could have a small makerspace that featured readily accessible tools and materials. These smaller “satellite makerspaces” would be networked to a larger makerspace, a “makerbase,” which would be located somewhere that receives a lot of traffic. A makerbase might look similar to the first design concept and would have access to more expensive equipment like laser cutters and 3D printers. Makers from the satellite makerspaces could design in their space and then send their designs to the makerbase for manufacturing via an internet connection. The next time makers needed to drive into town, they could stop in at the makerbase and pick up their parts, which would allow members from all parts of the Navajo Nation to have access to both basic and more advanced manufacturing equipment.

Another distinct advantage to this design is that its flexibility allows for the community to modify the list of design specifications to better meet their particular needs. With each community having its own makerspace, community members could tailor the materials, equipment, and types of projects to ones they find relevant. For example, if alternative energy is a high priority for a community, their makerspace could promote the tools and skills that they would need to implement solar or wind energy for their homes. As another example, if allocating a permanent location for the makerspace is an issue for a community, they could share a mobile makerspace with other communities.
Figure 6-6 shows an example of what this makerspace network might look like. The green area represents the Navajo Nation. The smaller blue pyramids signify the satellite makerspaces that are networked to the makerbases represented by the larger orange pyramids. Approximate distances between the makerspaces are provided to present a sense of scale. One should note that these are not straight-line distances; rather, they represent the number of miles it would take to drive from one community to another.

Each makerbase would require a website where makers from around the Navajo Nation could submit their files and view the status of their parts. This website could be similar to the one implemented by the Department of Mechanical and Aerospace Engineering’s Rapid Prototyping Facility at the University of Florida (University of Florida, 2015). Portable hotspots or tethered cell phones could provide internet to communities that may not have access to it. Alternatively, makers could deliver their files to the makerbase in person via a USB drive.

6.4 Analysis and Optimization

After the preliminary design concepts were developed, I presented them to the community to receive their feedback to refine the designs. In general, they were well-received; however, one community member asked why the first design concept featured three tables rather than four. While at first glance this appeared to be a minor detail, the man continued to explain that the number four was sacred to the Diné people. His question brought to light a more important concern; how well was the Diné concept of spirituality reflected in the design concepts?
Figure 6-6. Render of Design Concept 3
The role of spirituality in the Diné experience of making was an important finding in Chapter 4. It would make sense that spirituality should also play a significant role in the makerspace design, which presents a problem. As an outsider to the community, I cannot claim to have a firm understanding of traditional Diné spirituality. Due to this limitation, further refinement of the design concepts needs to be conducted by the community.

6.5 Discussion

6.5.1 Implications of Findings

The results of this study produced ten design specifications that informed three different design concepts for a Diné makerspace. Some of the characteristics of these concepts resemble those found in Western makerspaces, while others appear to be unique to this study. In this section, I discuss these areas of convergence and divergence between the Western and Diné understandings of makerspaces.

Many of this study’s design specifications reflect the common characteristics of makerspaces found in the literature. For example, the participants agreed with Bowler (2014) that making in a makerspace should be hands-on. Additionally, the participants’ descriptions of the makerspace being a physical place were found in most of the literature. However, there were some examples in the literature of makerspaces that were not permanent physical locations. One of them was a mobile makerspace used in a hospital (Nelson, 2015). The concept of a mobile makerspace was adapted to provide the foundation for the second design concept. Just as Sheridan et al. (2014) described how the Sector67 makerspace supports a variety of types of making from sewing to 3D printing, the participants also described a wide variety of types of making that they wanted to see in a Diné makerspace: from modern forms of making such as CNC
machining to more traditional forms like weaving. Additionally, the participants agreed with Martinez (2015) that it would be important for the users of the makerspace to have the freedom to choose projects that are meaningful to them.

The makerspace network described in the third design concept is like MIT’s makersystem (MIT Project Manus, 2017). This concept of networking makerspaces has implications at the national and perhaps international level as the issue of small remote communities not having access to a makerspace is not something unique to the Navajo Nation. I believe that there are many other rural communities that could benefit from a similar makerspace network.

One finding that I did not encounter in the literature was the participants’ desire to use their own tools. It should be noted that all of the participants were over the age of 18 years old and may have been more prone to see making as a form of income. A makerspace designed for younger makers that focuses more on education may not require this specification. Another unique finding was how the first design concept was laid out. While other researchers have noted the importance of how everything in a makerspace is arranged (Petrich et al., 2013), Design Concept 1 was the first time I had encountered a makerspace design that directly integrated the Diné process of internalizing knowledge. Incorporating this process into the design of the Diné makerspace may not only resonate with more traditional Diné makers, but this design could also be incorporated into other makerspaces to help Western makers better understand the steps in the making process as well as the circular and iterative nature of making.
Another unique finding from this project is the importance of emphasizing who is made over what is made, which has interesting implications for how the makerspace is implemented. For example, one way to emphasize who is made with the mobile makerspace design concept would be to include a scrapbook in which each community could display photos of the people that have used the makerspace, helping to foster a community of making across the Navajo Nation. Additionally, teachers write tests and develop curricula as part of their job. However, if people ask teachers how they measure their success, they will not talk about the number of tests given. Instead, they measure it by the number of students that they have helped to prepare for the future. Within the many Western makerspaces used to educate and excite makers in STEM disciplines, I believe that it is important for the facilitators of these makerspaces to also keep this perspective in mind when deciding how they are to ultimately measure their makerspace’s success.

6.5.2 Study Limitations

The first major limitation is that my understanding of the Diné philosophy of learning and the Diné process for internalizing knowledge is at best superficial. Appropriately incorporating this aspect of the Diné culture into the makerspace design would require significant involvement from the community. Another limitation comes from the location of the study and the resulting participant sample. Many of the students who were interviewed work and take classes in what many would consider a Western makerspace. As a result, it can be expected that their ideas about what a Diné makerspace might look like would resemble NTU’s Fabrication Lab. For example, Participant N was asked to imagine a place where students could go to learn about
STEM through hands-on projects. When she was then asked what she thought that space would look like, she responded:

Um, I would say that would be something close, similar to the Fab Lab. A building filled with things where you could go ahead and make projects. And I would have, basically things like the Fab Lab, where you have 3D printers, you could have CNC machines, you could also have robotics, computers, but I don’t, I think that would be in a separate section because of the sawdust. But, other than that, I think it would be similar to that, with a lot of books and stuff.

It is likely that had this study been conducted at a different site where the participants did not have any previous knowledge about what a makerspace might look like, there would have been different results.

The final limitation to be discussed is related to the derived design specifications. As mentioned previously, an engineering design specification needs to be specific enough that it is possible to determine whether or not it has been met without any ambiguity. Some of the specifications generated in this project like, “the makerspace should be environmentally friendly” lack this level of specificity. However, the Navajo Nation is not a homogenous group of people, for many of its communities have needs unique to themselves. To derive a list of design specifications general enough to apply to the whole Navajo Nation, some specificity had to be given up. It is better to not think of them as design specifications, but rather as design suggestions. It is left to the individual communities to refine these suggestions into specifications that are relevant to their unique needs.

6.6 Summary

In this chapter, I addressed the modified second research question: How can the Navajo experience of making be integrated to design a culturally-contextualized makerspace? After formally identifying the need for this project, ten design
specifications for the Diné makerspace were derived from analyzing the interview data. These specifications informed the generation of three unique design concepts of a culturally-contextualized makerspace for the Navajo Nation. To help refine these design concepts, they were then presented to the community to receive their feedback. After discussing each of these steps of the engineering design process, I concluded this chapter by discussing the implications and limitations of the presented findings.
CHAPTER 7
BROADENING THE WESTERN MAKING MENTALITY

While conducting this study, I found my Western understanding of the experience of making challenged in a variety of ways. Upon reflection, this project has broadened my understanding of making in four areas, none of which were adequately addressed in any of the previous chapters. This chapter discusses each of the different ways my making mentality was expanded while working on this project.

7.1 Who Are the Makers?

One of the questions that was asked of the participants was, “do you consider yourself a maker?” While the term maker meant different things to different participants, most of them did consider themselves makers. For example, Participant B stated that he was a maker because he had “the knowledge of knowing how to put things together,” while Participant C explained that it was his “ability to make another human. [laugh].” In addition to themselves, the participants gave examples of other people they considered makers including engineers, artists, and children. Participants even made the claim that everybody is a maker.

We are all makers. This theme is a reoccurring one that appears throughout the Western making community. However, it is important to question, what does this statement truly mean? Is it simply that all humans are born with the potential to make? If so, that would suggest making is an active process. While everyone has the potential to make, one would still need to make the choice to do so. In We Are Makers, a Ted Talk, one of the Maker Movement’s leading voices, Dale Dougherty (2011), explained, “We don’t just live, but we make. We create things.” By using the word but, Dougherty frames making as something that exists alongside but separate from the act of living.
One of the participants of this study had a different perspective. When Participant Y was asked, “What do humans make?” she responded, “carbon dioxide. [laugh].” This response was likely intended to be a joke, but her response reinforces just how ingrained making is to the act of living. Seen from this perspective, making and living are one and the same phenomenon. People cannot live without making. With every exhale, a person is making carbon dioxide and thus helping to foster life for Earth’s plants. Humans are not makers because they have made a choice to realize their potential to create, they are makers because they simply exist. When asked if she thought making was part of human nature, Participant Y responded, “It’s part of human, even animal nature, I mean, it's part of nature basically,” which is a profound realization that has implications for the Western making community. Those in the Maker Movement are constantly trying to promote its message that we are all makers to encourage more people to participate in making. However, people from the United States have been consumers of goods for so long, it may be difficult to convince them that they are indeed makers. Presenting making from this perspective may make it easier to change their minds.

7.2 Where Does Making Begin?

Another area where the Diné perspective has the potential to broaden the Western understanding of making is what makers consider to be the first step in their project. Looking through the different projects that were highlighted in one Make: magazine showed initial steps such as “prep the modules” (Ragan, 2014, p. 76), “make the cup holder” (Gurstelle, 2014, p. 93), and “solder” (Bakker, 2014, p. 98). In contrast, some of the participants in this study had a much wider view of which steps should be
considered a part of the making process. For example, Participant Y described weaving a rug in the following way:

I mean, you have to raise your sheep in order to have wool and so it, it goes back down to that, I mean. Right now you can buy string and yarn from Walmart if you want to or from your trading post but, uh, but how I taught myself and the way I saw my grandmother was that it goes back down to the sheep. And if you can’t raise your sheep, you can’t have wool and you can’t weave a rug. So how, how do you expect to finish a rug when you can’t even take care of a sheep? And then that goes back down to your land, I mean, if you overgraze it, how are you going to feed your sheep?

For Participant Y, the act of weaving does not begin with gathering materials or preparing her loom. Rather, it starts by taking care of the land so that her sheep are healthy and able to provide wool: an activity that from the Western perspective is considered independent and unrelated to weaving.

Two aspects of this holistic making perspective are valuable both in the making community, as well as the engineering field. The first aspect is that it demonstrates an awareness of the complex relationships that exist among different disciplines: in this case farming and weaving. The types of problems that face today’s engineers are increasingly interdisciplinary. For example, robotics requires the knowledge of mechanical and electrical systems in addition to computer programming. An engineer who has a perspective similar to Participant Y’s would be in a better position to think about a robot holistically, and therefore understand the complex relationships among the sensors, actuators, and software. One of the common problems in robot design that I have experienced is when some of the engineers becomes so focused on their particular tasks, they lose sight of how their part of the robot integrates with the whole. This phenomenon might manifest itself in a programmer assuming that the robot’s actuators can move faster than their physical limits, or a mechanical engineer not
considering how the placement of a motor may affect the performance of the robot’s electronics. Engineers who have a holistic perspective similar to Participant Y’s would have considered these relationships during the early stages of the design process, allowing them to better anticipate and address any potential flaws in their initial designs.

The second aspect of this perspective is the ability to see the big picture. As the world’s population continues to grow and resources become scarce, it becomes increasingly more important that makers and engineers understand the impact that their designs have not only on today’s environment, but on tomorrow’s environment as well. Understanding that what is made today has an impact on what it is possible to make in the future is a valuable perspective that should be promoted in Western making and, ultimately, the engineering field.

7.3 What Do the Makers Make?

The outcome space that emerged from the phenomenographic portion of this study addressed the question: Why do the Navajo make? However, this is just one piece of the broader research question: In what ways do the Navajo describe the experience of making? While analyzing the interview data, I noticed that the examples of making that the participants provided were richly diverse. A list of these different forms of making was generated from the transcripts, and each example was matched to one of the categories of the outcome space based on the context in which it was described. For example, Participant X described how the knowledge of being able to design artwork could take someone far. As a result, artwork was matched with the self-actualization category. It was possible that two participants could provide the same example, but each instance of that example would be matched with different categories due to the different contexts in which the participants described their examples. For
instance, one participant may have described a hogan as a shelter that helps people to survive, while another acknowledged the spiritual component of a hogan by describing it as a sacred place. As a result, the first example would be placed in the survival category while the other would be placed into spirituality. Other examples were left uncategorized if it was not clear to which category an example would belong. A sample of these different forms of making and how they were coded is shown in Table 7-1.

Table 7-1. Examples of the different forms of making described by participants

<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>Example</th>
<th>Justification</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>J</td>
<td>rug weaving</td>
<td>was her grandma's livelihood</td>
<td>Survival</td>
</tr>
<tr>
<td>S</td>
<td>tools</td>
<td>making driven by need</td>
<td>Survival</td>
</tr>
<tr>
<td>E</td>
<td>fry bread</td>
<td>joked that one needed to know how to make fry bread if they wanted to get a husband</td>
<td>Society</td>
</tr>
<tr>
<td>L</td>
<td>daughter's hair</td>
<td>learns from others via tutorials and pictures</td>
<td>Society</td>
</tr>
<tr>
<td>M</td>
<td>banana bread</td>
<td>prefers to make rather than buy because she believes her products are the best</td>
<td>Pride</td>
</tr>
<tr>
<td>B</td>
<td>work as a lineman</td>
<td>proud of being able to provide a community with electricity</td>
<td>Pride</td>
</tr>
<tr>
<td>T</td>
<td>opportunities</td>
<td>he made opportunities that allowed him to experience things he may not have experienced otherwise</td>
<td>Self-actualization</td>
</tr>
<tr>
<td>M</td>
<td>Navajo water basket</td>
<td>weaves to satisfy her yearning to learn</td>
<td>Self-actualization</td>
</tr>
<tr>
<td>T</td>
<td>a path</td>
<td>proudest achievement is helping to pave the way for others</td>
<td>Transcendence</td>
</tr>
<tr>
<td>Y</td>
<td>making STEM a priority within the Navajo Nation</td>
<td>believes it would benefit the people of the Navajo Nation</td>
<td>Transcendence</td>
</tr>
<tr>
<td>E</td>
<td>morning offerings</td>
<td>form of prayer</td>
<td>Spirituality</td>
</tr>
<tr>
<td>Y</td>
<td>thoughts</td>
<td>process of thinking is sacred</td>
<td>Spirituality</td>
</tr>
<tr>
<td>B</td>
<td>babies</td>
<td>-</td>
<td>Uncategorized</td>
</tr>
<tr>
<td>L</td>
<td>a supercomputer</td>
<td>-</td>
<td>Uncategorized</td>
</tr>
</tbody>
</table>
There appears to be a consensus in the Western making community that making involves the production of physical or virtual objects (Vossoughi & Bevan, 2014). For example, one study defined makers as “an interdisciplinary collective of engineers, scientists, hobbyists, and artists who are focused on the creation of physical artifacts that usually incorporate technology” (Foster et al., 2015, p. 2). Despite this common understanding, many of the participants gave examples of making that were more abstract than those that would typically be considered making. For instance, when Participant B was asked if survival was part of the role that making has played in the Diné culture, he responded, “Survival and you got to learn how to make jokes, you know. If you don’t know how then it’s just really serious, you know, and then people get tired of your company.” When asked to give some examples of making that he had seen in Navajo culture, Participant B also mentioned that “they know how to make time for the-, for their loved ones, you know, for family.” For Participant C, communication itself was a form of making. He described how writing a book could be considered making and then went on to say “and that’s making, you know, you’re basically putting words inside a person’s head and they’re actually, you know, imagining that stuff in their heads, you know.”

In addition to these abstract forms of making, the participants gave many other examples that would typically be considered outside of the Western understanding of making. Examples of the many different forms of making found in this study were compiled into the word cloud shown in Figure 7-1. While not exhaustive, this word cloud captured the diversity of making that exists within the Navajo Nation. Although there is
no order to how the words are arranged in the cloud, each example was color-coded according to the category that it best fit.

Figure 7-1. Word cloud representing the diversity of Diné making
The Diné are known for their skill in making jewelry, rugs, baskets, and other traditional crafts. However, perhaps their achievement in these forms of making has caused the rest of the world to typecast them. I hope that this word cloud will challenge the rest of the world to see the Navajo Nation as a community that makes more than just traditional crafts. Additionally, I hope that this word cloud may also challenge the people of the Navajo Nation to recognize all of the incredible forms of making that they themselves do. Finally, I hope that this word cloud might also challenge Western makers to broaden their own understanding of making so that they might recognize all of the extraordinary forms of making that exist beyond the scope of what the Western making community has traditionally considered making.

As previously mentioned, the general consensus in the Western making community appears to be that making involves the generation of physical or virtual artifacts. While this is certainly an important component to making, many of the participants gave more abstract examples of things that are made on the Navajo Nation like jokes, opportunities, time for their loved ones, morning offerings, and a legacy. While none of these are things that one will find featured at a Maker Faire or on the cover of *Make*: magazine, I believe that these are equally important forms of making that have the potential to challenge how the rest of the world defines making.

7.4 Who Do the Makers Make?

The last important finding that I would like to discuss from this study is the concept that *who* is made is more important than *what* is made. While I touched upon it earlier in Chapters 4 and 6, I believe that it is important enough to warrant further discussion. The best way to understand this concept is through Participant E’s own words:
I think about my grandma when I think about a maker. She really made some cool rugs. She made me some cool shirts like Na-, Na-, Navajo traditional style shirts. Um, I think about her the most, um, she was a young girl and you know, her family was not very kind to her. They really treated her badly. Um, you know, when she came of age, um, she had opportunity to marry. And while she didn’t really want to, um, she married my, my grandfather, you know, because he came and he asked for her hand and you know, he provided the horses for, for, for her family so she, she, she had to marry him and she went with him. And so she went from a bad environment to being married to my grandfather who was fairly wealthy for a Navajo man. He had a lot of land and a lot of cattle and horses. He was a pretty, pretty well-off guy. And she created this whole family, like I have, uh, 13 aunts and uncles. My mom would make them 14. And there are a few that didn’t survive their infancy. And she created this huge family and this huge legacy that we, that we, you know, identify ourselves with as [clan name]. And we have this home in the mountains. We have, you know, the winter ranch at [small community on the Navajo Nation] where I live now. And it’s like incredible. Like we have a hogan, we have songs, we have, um, teachings, we have values. She made us what we are now. And you know, in, in her old age she’s, she told me that, you know, she wasn’t, ha-, she didn’t have much, you know, growing up as a girl and she was, you know, treated very harshly and, but you know, my grandfather with him she created this whole family that she had. You know, she passed a few years ago but you know, she, her family was the greatest thing that she felt that she could’ve, ha-, she could have accomplished or achieved and, and she was very proud of us. Like she, she made this whole, whole thing, you know, this whole [clan name] family, this whole clan and it’s huge now. And, um, another thing that comes to my mind is my, my, my paternal grand, grandmother. My náli [paternal grandmother], um, she said that the most important thing for a Navajo person was to continue themselves. And she like, saying that in Navajo like it’s kind of, you kind of have to interpret that for yourself. And the way to understand it is, you know, you have Navajo children. You teach them a Navajo way of life. And you teach them to be Navajo and speak Navajo. And you create that and you continue it, you know, for generations to come. And so that, as a, as a maker that is one of the most important things that I think of, you know, creating Navajo beings who are, you know, very knowledgeable, very, very, very grounded and you know, intelligent and resourceful. That make, making that, you know, creating that would be a lifetime achievement. [laugh] So that, that includes everything, you know, the weaving, any jewelry making, any, any songs, and even how to pray, you know, that is a, a great [indecipherable] incredible, um, talent.
Participant E’s explanation of her understanding of making is a powerful one. From her perspective, all of the forms of making, whether they be physical, virtual, or abstract, all serve one ultimate purpose: to help prepare the next generation of Navajo people.

While Gutwill et al. (2015) used the word tinkering instead of making to emphasize the process of making over the products that are made, the findings of this study suggest that it should be taken one step further in that making should emphasize the people who are being made rather than the process or the product. To an extent, the Maker Movement has acknowledged this importance. For example, at the end of his Ted Talk, Dale Dougherty (2011) asked the question: “What will America make?” His response was, “It’s more makers” (Dougherty, 2011). However, this message is not consistent enough.

The following is an example of how the Western making community could benefit from this broadening of the understanding of making. Many Western makerspaces showcase the types of artifacts that have been made there. Having a visual for what can be made in that space might inspire a future maker (Kurti, Kurti, & Fleming, 2014). Seeing these items, someone might think, “Awesome! I can make that, but if I change this, I might be able to make it better or perhaps make something completely new.” Instead of a makerspace showcasing these physical artifacts, perhaps it would be more beneficial to showcase the people who have worked in that space. That would make it possible to change the internal dialogue to “Awesome! I can be like them, or perhaps I can build on what they have accomplished and reach even greater achievements.” This type of makerspace would not be framed as a place where people work together to
make things, but as a place where people work together towards achieving their potential through making.

**7.5 Discussion**

At this point, some readers may be wondering, *Yes, the Diné perspective does indeed broaden the Western understanding of making. However, is it appropriate to do so? Perhaps there is a reason that the Western making community does not consider making time for loved ones as a form of making. Is there even a need to broaden our understanding of making?* These are valid questions and echo the thoughts that I myself had while working on this project. Is there a need to broaden the Western understanding of making? I believe the answer to this question is a definitive, *yes.*

Earlier in this document, I discussed how the Maker Movement has been criticized for not being fully inclusive. One of the reasons people may not consider themselves makers is that the activities often promoted by the Maker Movement (e.g., robotics or 3D printing), are not ones that they associate with themselves. By broadening what activities are considered making, it will be easier for people who would not traditionally see themselves as makers to become interested in joining the making community.

The next concern that some readers might be having is, *Yes, perhaps there are some forms of making that are marginalized and the Western making community could do a better job incorporating them into the conversation on making, but there must be a limit. Is considering making time for loved ones as a making activity going too far?* Perhaps. Perhaps not. How the Diné perceive and prioritize time may provide insights on how Western makers could better manage a project’s timeline or how to find balance between working on making projects and other aspects of life. The making community uses playful exploration to find creative uses for objects that others may not see as
having any value. I believe that researchers should foster this same open-minded attitude when conducting research on making. While it is not obvious to me how *making a wish* is related to promoting STEM education, it is possible that a creative reader may see a connection and become inspired to act upon it.

### 7.6 Summary

Key players in the Maker Movement have come under criticism for not fostering the same level of inclusivity that the movement has come to represent. This lack of inclusivity serves as a detriment both to the Western making community, as well as the makers who have been marginalized by it. To address this issue, the aim of this chapter was to add one of those voices, the voice of the Diné, to the conversation of how the terms *making* and *maker* are defined. In particular, the perspective of the Diné challenges how one is defined as a *maker*, what steps are considered part of the making process, what things people produce that are seen as making, and what the ultimate goal of making should be.
CHAPTER 8
CONCLUSION

8.1 Summary

In this study, I worked towards addressing the underrepresentation of Native Americans in the engineering field by developing multiple design concepts for a culturally-contextualized makerspace. Due to the Diné people’s unique understanding of making, it is inappropriate to simply build a Western makerspace on the Navajo Nation. Instead, it is important that any makerspace on the Navajo Nation be designed in a way that allows it to be both responsive and respectful to the unique needs and worldviews of the Diné.

To accomplish this, I attempted to answer the modified first research question: In what ways do the Navajo describe the experience of making? Using phenomenography and Maslow’s theory of human motivation, I found that community members described their experience of making primarily in terms of motivations. These motivations formed a hierarchy where the forms of making that emphasized making other people in the community were the ones that participants most valued. Additionally, the participants acknowledged a spiritual component to the act of making, a concept I had not encountered in the literature.

With an improved understanding of how the Diné describe the experience of making, I then attempted to answer the modified second research question: How can the Navajo experience of making be integrated to design a culturally-contextualized makerspace? Using the findings from the first portion of the study, along with the interview data, I developed the design specifications for a culturally-contextualized
makerspace for the Navajo Nation. These specifications informed the development of
three design concepts for the makerspace.

In the first design, the physical layout of the room reinforced the Diné process of
internalizing knowledge. The second design had the ability to reach even the most
remote areas of the Navajo Nation due to its portable nature. Finally, the third concept
was a network of makerspaces that had the potential to provide access to making
opportunities across the entire Navajo Nation. One unique finding in this study was the
design specification that the makerspace should focus on celebrating who is made
there, not what is made. This concept was addressed further in Chapter 7, where I
reflected upon the unique ways in which the Diné understand the experience of making.
Their understanding provides a counter-narrative to how the Western making
community defines making as well as who is considered a maker and why.

8.2 Recommendations for Further Research

While attempting to answer the research questions, this project generated many
more potential topics for additional research. The modified first research question was
posed to address the gap in the literature regarding the unique ways in which the Diné
understand the experience of making. To help answer this question, I used Maslow’s
(1943) theory of human motivation. In Chapter 4, I discussed some of the ways in which
the findings of this study deviated from Maslow’s theory, generating opportunities for
further research. For example, additional investigation would be required to determine if
Maslow’s theory requires an adjustment to account for spiritually motivated behaviors.

The model that was developed in Chapter 4 is only one incomplete portion of
how the Diné understand the experience of making. To expand this understanding, I
recommend that a researcher from the community further explore the role that
spirituality plays in the act of making for the Diné. Another way to further illuminate the outcome space is for a similar phenomenographic study to be conducted in a different part of the Navajo Nation. Some of the most interesting findings of this study came from participants who were not studying engineering courses and did not regularly interact with NTU’s Fabrication Lab. Replicating this study with another population on the Navajo Nation that has no awareness of Maker Faires or of fabrication labs could help to generate a more complete understanding of how the Diné describe the experience of making.

The location of the study was not the only factor that influenced the results. As mentioned in Section 3.9, my biases and life experiences determined which theoretical frameworks were potentially available to this study. It would be interesting to see what the results would be if a community-led research group conducted a similar study using a community framework such as the one developed by Benally (1994). It is also important to note that the Navajo Nation is just one community. I believe that the Western making community can further broaden and augment their own understanding of making by looking at the unique ways that other groups marginalized by the Maker Movement understand the experience of making.

Regarding the makerspace, much work needs to be done to refine one of the design concepts into a functional makerspace. This process includes working with the community to appropriately incorporate the Diné concept of spirituality into the design, determining whether or not the makerspace should exist in a fixed location, deciding what types of tools and materials it should have, and determining how the makerspace should be funded. Once the design of a makerspace for a specific community has been
finalized, the next step is to build the space. In parallel, more research needs to be conducted to develop culturally-contextualized curricula to be implemented in the makerspace. Once both of these tasks have been completed, the final step will be to evaluate the effectiveness of the makerspace to promote interest in and exposure to engineering careers on the Navajo Nation.

Within just one small portion of a community, I encountered a bonanza of unique ways that people understand the experience of making. One can imagine what else the Western making community will learn if more of these marginalized voices are included in the Maker Movement. For example, the participants of this study brought to light the concept of abstract making. How does the process of abstract making differ from that of making physical artifacts? How can the abstract forms of making that people already engage in be used as leverage to promote interest in engineering careers? I advocate for the Western making community to continue to ask questions like these and challenge how making is defined as well as who is defined as a maker. While there still may yet be a boundary to the useful ways that the Western making community understands the experience of making, if such a boundary does exist, I believe that it has not yet been reached.
July 22, 2016

Daniel Frank, MS
University of Florida

Dear Mr. Frank,

This is to advise you that the Study #NNR-16.251T “Investigating Culturally-Contextualized Making with the Navajo Nation” has been placed on the Agenda of the Navajo Nation Human Research Review Board (NNHRRB), on July 19, 2016 and the following action taken subject to the conditions and explanation provided below.

<table>
<thead>
<tr>
<th>On Agenda For:</th>
<th>Procedure</th>
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<tbody>
<tr>
<td>Reasons:</td>
<td>New Title</td>
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<tr>
<td>Description:</td>
<td>Request Review and Approval of New Study</td>
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<tr>
<td>NNHRRB Action:</td>
<td>ACCEPTED AND APPROVED from July 19, 2016 – July 19, 2017 period</td>
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<td>Conditions:</td>
<td>With Changes Requested, with All Standard Conditions</td>
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The Navajo Nation Human Research Review Board has added a very important additional contingency regarding failure to comply with NNHRRB rules, regulations, and submittal of reports which could result in sanctions being placed against your project. This could also affect your funding source and the principal investigator. Under Part Five: Certification, please note paragraph five wherein it states: “I agree not to proceed in the research until the problems have been resolved or the Navajo Nation Human Research Review Board has reviewed and approved the changes.” Therefore, it is very important to submit quarterly and annual reports on time and if continuation is warranted submit a letter of request sixty (60) days prior to the expiration date.

The following are requirements that apply to all research studies:

1. The Navajo Nation retains ownership of all data obtained within its territorial boundaries. The Principal Investigator shall submit to the NNHRRB a plan and timeline on how and when the data/statistics will be turned over to the Navajo Nation;
2. Only the approved informed consent document(s) will be used in the study;
3. Any proposed future changes to the protocol or the consent form(s) must again be submitted to the Board for review and approval prior to implementation of the proposed change;
4. If the results of the study will be published or used for oral presentations at professional conferences, the proposed publication, abstract and/or presentation materials must be submitted to the Navajo Research Program for Board review and prior approval;
5. Upon Board approval, three (3) copies of the final publication must be submitted to the Navajo Research Program;
6. All manuscripts must be submitted to the Navajo Research Program for Board Review and prior approval;
7. The Principal Investigator must submit a dissemination plan on how the results of the study and how these results will be reported back to the Navajo Nation;
8. The Principal Investigator must share specifically how these results will generally benefit or improve the health of the Navajo people. This can be completed by:
   a. Conducting an educational in-service for the community people and health care providers on the Navajo Nation and present the findings. Provide documentation of these in-services presented.
   b. Developing educational materials for use by the health care providers and the community people and providing the training on how to use the materials; and
   c. Presenting and sharing the results of the study at a research conference sponsored by the Navajo Nation for its health care providers and the Navajo people.

9. The Principal Investigator is expected to submit documentation on 8a, b, & c;
10. The Principal Investigator must submit quarterly and annual reports as scheduled.

Please begin using Protocol Number NNR-16.251 on all correspondences relating to this study. If you have any questions on this subject, please call the Navajo Research Program at (928) 871-6929.

Sincerely Yours,

Beverly Becenti-Pigman, Chairperson
Navajo Nation Human Research Review Board

cc: #NNR-16.251 file
DATE: 6/10/2016
TO: Daniel Frank
FROM: Ira Fischler, Ph.D., Professor Emeritus
      Chair IRB-02
IRB#: IRB201600888
TITLE: Investigating Culturally-Contextualized Making with the Navajo Nation

You have received IRB approval to conduct the above-listed research project. Approval of this project was granted on 6/10/2016 by IRB-02. This study is approved as expedited because it poses minimal risk and is approved under the following expedited category/categories:

7. Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies. [Note: Some research in this category may be exempt from the HHS regulations for the protection of human subjects. (45 CFR 46.101(b)(2) and (b)(3).) This listing refers only to research that is not exempt.]

Principal Investigator Responsibilities:

The PI is responsible for the conduct of the study.

- Using currently approved consent form to enroll subjects (if applicable)
- Renewing your study before expiration
- Obtaining approval for revisions before implementation
- Reporting Adverse Events
- Retention of Research Records
- Obtaining approval to conduct research at the VA
- Notifying other parties about this project’s approval status

Study Team:

Carl Crane    Study Coordinator
APPENDIX C

NAVAJO NATION HISTORIC PRESERVATION DEPARTMENT PERMIT

THE NAVAJO NATION

P.O. Box 4950 • Window Rock, Arizona 86515 • (928) 871-7198

Russell Begaye
President

Jonathan Nez
Vice President

May 20, 2016

Daniel Frank

Dear Mr. Frank:

Enclosed is the Naveajo Nation Cultural Resources Investigation Permit No.: C16025-E for a period BEGINNING August 15, 2016 & ENDING December 31, 2016, to conduct ETHNOGRAPHIC STUDIES WITHIN THE CROWNPONTE COMMUNITY. THE GOAL IS TO LEARN HOW THE NAVAJO VIEW AND UNDERSTAND THE CONCEPT OF MAKING ARTIFACTS AS WELL AS ENGINEERING. THE RESULTS OF THE DATA WILL BE USED TO INFORM WORKSHOPS ON MAKING WHAT WILL BE PRESENTED TO THE CROWNPONTE COMMUNITY AS WELL AS OTHER COMMUNITIES ON THE NAVAJO NATION.

If you have any questions, please call Tamara Billie at (928) 871-7880, or email tbillie@navajo-nsn.gov. Thank you.

Sincerely,

Ora Marek Martinez, Department Director
Navajo Nation Historic Preservation Department
THE NAVAJO NATION
CULTURAL RESOURCES INVESTIGATION PERMIT

PERMIT NUMBER: C16025-E

Pursuant to the authority of Section 302 of the Navajo Nation Cultural Resources Protection Act (CMY-19-88), permission is hereby granted to Daniel Frank to conduct ETHNOGRAPHIC STUDIES WITHIN THE CROWNPOINT COMMUNITY. THE GOAL IS TO LEARN HOW THE NAVAJO VIEW AND UNDERSTAND THE CONCEPT OF MAKING ARTIFACTS AS WELL AS ENGINEERING. THE RESULTS OF THE DATA WILL BE USED TO INFORM WORKSHOPS ON MAKING WHAT WILL BE PRESENTED TO THE CROWNPOINT COMMUNITY AS WELL AS OTHER COMMUNITIES ON THE NAVAJO NATION.

1. Name and Title of Person in:
   A. General Charge: Daniel Frank
   Direct Charge: Darryl Williams, Aaron Johnson and Fay Shaw
   B. Project Members: AS ABOVE

2. On Lands Described as Follows: Crownpoint Chapter, McKinley County, New Mexico NMPM.


4. Standard Stipulations: This permit is granted subject to the Permittee adhering to the following stipulations. Failure to conform strictly to these conditions may result in suspension or revocation of this Permit and may affect the Permittee’s ability to obtain similar Permits from the Navajo Nation in the future.
   A. The Permittee will provide five days advance written notice to the Historic Preservation Officer prior to initiation of any of the activities authorized under this Permit. The Permitted will also provide written notice to the Historic Preservation Officer upon the completion of field work authorized under this permit. THIS IS NECESSARY ONLY FOR NON-SECTION 106 CLASS C ETHNOGRAPHIC PERMITS
B. A copy of this Permit must be in the possession of field workers at all times when they are conducting field work under the authority of this Permit.

The Permittee will exclusively employ Navajos for all positions to the extent that qualified Navajos are available.

C. This Permit is not a grant of authority.

1. Prior to initiating field work, the permittee must notify Chapter Officials (President, Vice President, Secretary, or Manager) to familiarize them with the proposed field work and the provisions of the Permit.

2. The Permittee must inform any potential interviewee that he/she is not required to consent to interviews or to cooperate otherwise with the Permittee.

   (a) If the interviewee does consent to be interviewed, the researcher must get the signed consent of the interviewee for publication and other use of the information, use of their name, and how they are to be given credit for providing information. THIS IS NECESSARY ONLY FOR NON-SECTION 106 CLASS C ETHNOGRAPHIC PERMITS

   (b) Reports and publications will follow conditions set by the interviewees on publication of information, use of their names, and how they are to be credited. THIS IS NECESSARY ONLY FOR NON-SECTION 106 CLASS C ETHNOGRAPHIC PERMITS

PERMIT GRANTED,

Ora Marek-Martinez, Department Director
Historic Preservation Department
APPENDIX D
CROWNPOINT CHAPTER RESOLUTION LETTER

RUSSELL BEGAYE
NEZ
President

NAVAJO NATION

JONATHAN

CROWNPOINT CHAPTER

Vice

CHAPTER ADMINISTRATION
Role: Mattie Otero. Community Services Coordinator
Email: remarks@navajochapters.org
Aaron Editty. Accounts Maintenance Specialist
Email: aeditty@navajochapters.org

RITA M. CAPITAN
President

CECILIA J. NEZ
Vice President

JERELLENE KING
Secretary/Treasurer

JONATHAN FERRY
Council Delegate

HERBERT ENDCO
Land Board Member

RESOLUTION 16-04-001

SUPPORTING AND APPROVING A RESEARCH STUDY IN INVESTIGATING CULTURALLY-CONTEXTUALIZED MAKING WITH THE NAVAJO NATION BY DANIEL FRANK, A STUDENT AT THE UNIVERSITY OF FLORIDA AS PART OF A DISSERTATION STUDY.

WHEREAS:

1. The Crownpoint Chapter Certified as a local governmental unit of the Navajo Nation authorized by 2 N.R.C. 4001 and 4028 (a) to review and promote matters that affect the local community and to make appropriate recommendations to the Navajo Nation, Federal, State, County and local agencies for consideration and approval; and

2. The Crownpoint Chapter is a recognized and certified chapter authorized under Navajo Nation Code Title 26 Local Governance Act of 1998; and

3. By Resolution CAP-34-98, the Navajo Nation Council approved the “Local Governance Act” wherein the Navajo Nation delegated government authority to the Chapter of the Navajo Nation to address matters of local concern with Navajo Law Custom and tradition; and

4. Crownpoint Chapter exercises authority to review, resolve, approve, recommend, support and provide assistance to local communities on matters within the Crownpoint Chapter and perhaps neighboring communities it being in the best interest of the people. As an inherent power of Governance Act, 28 N.N.C. et seq., re-delegated each chapters by statute of authority of local government functions to improve local governmental structure and provide an opportunity to make decision making, allow communities to excel and flourish, enable Navajo leaders to lead toward a prosperous future and improve, strengthen and sovereignty of the community and the Navajo Nation; and

5. Crownpoint Chapter is responsible in partnership to provide and ensure the well-being, safety and health of community members; and

6. Daniel Frank, a student at the University of Florida, is a candidate for a PhD in Mechanical and Aerospace Engineering; and

7. As a requirement to complete the study program. Student Daniel Frank is required to conduct a study of a subject related to the field of investigating culturally-contextualized making with the Navajo Nation in which input from the Navajo individuals will be collected, analyzed, compiled, evaluated and disseminated; and

8. All human subject studies conducted on the Navajo Nation are required to comply with laws, policy, procedures, guidance, and protocols of the Navajo Nation.
NOW THEREFORE BE IT RESOLVED THAT:

1. Crownpoint Chapter supports and approves a research study in investigating culturally-contextualized making with the Navajo Nation by Daniel Frank, a student at the University of Florida as a part of a dissertation study.

CERTIFICATION

CROWNPOINT CHAPTER, CERTIFY, THAT THE FOREGOING RESOLUTION, was duly considered by Crownpoint (Navajo Chapter) New Mexico, at a duly called Chapter Regular Meeting at which a quorum was present and that same was passed by a vote of 28 in favor, 0 opposed, and 4 abstained on the 19th day of April, 2016.

MOTION: Sandra Jeff

SECOND: Corey Healy Tully

Rita Capitan, Chapter President

Cecilia J. Nez, Chapter Vice-President

Jerriene King, Secretary/Treasurer

Herbert Enrico, Land Board

Jonathan Perry, Council Delegate
APPENDIX E

LETTER OF SUPPORT FROM NAVAJO TECHNICAL UNIVERSITY

June 2, 2016

Navajo Research Program
Navajo Department of Health
P.O. Box 1390
Window Rock, Arizona 86515

Dear Navajo Nation Human Research Review Board,

I am writing on behalf of Navajo Technical University to confirm our institution’s support for the research project entitled “Investigating Culturally-Contextualized Making with the Navajo Nation.” Navajo Technical University currently operates a fabrication lab on campus for students to work on educational projects as well as personal projects. The lab is outfitted with industrial 3D printers, smaller personal printers, a host of electronic fabrication equipment, a CNC machine, 3D software, and state of the art inspection/reverse engineering equipment. Students utilize the lab foremost to reinforce their education in STEM, but also to explore the technologies and broaden their creativity. NTU views this project as aligning well initiatives in making that NTU has already begun such as the Navajo Nation Maker Faire (supported by NSF) and a TCU Maker Faire (supported by AIHEC). This project, in our view, will help increase enrollment at NTU in the STEM areas with both traditional and non-traditional students by exposing students and community members to the maker movement and foster more curiosity in the technologies related to the movement.

I understand that Navajo Technical University’s role in this project is to help members of the research team to connect with Navajo Technical University students, faculty members, and alumni to discuss their careers and education in making and engineering. NTU is also willing to use its facilities to host the maker workshops that develop from these interviews. NTU is also happy to accept the services of Daniel Frank, a PhD student in mechanical engineering at the University of Florida, during the fall of 2016. Navajo Technical University looks forward to being involved in this important project.

Sincerely,

[Signature]

Dr. Elmer J. Guy
President, Navajo Technical University
APPENDIX F
INFORMED CONSENT FORMS

Study ID: IRB201600888 Date Approved: 6/10/2016 Expiration Date: 6/3/2017

Informed Consent: Interview Phase (Adults: 18+ years old)

Protocol Title: Investigating Culturally-Contextualized Making with the Navajo Nation

Please read this consent document carefully before you decide to participate in this study.

This is a research study being conducted by Daniel Frank (Principal Investigator), a graduate student from the University of Florida, who is supervised by Dr. Carl Crane.

Purpose of the research study: The purpose of the study is to understand and describe how the Navajo view the concept of making artifacts. This information will be used to design a place that is aligned with the Diné culture and values where students can engage in hands-on learning of science, technology, engineering, and math.

Time required: Approximately 60 minutes

What you will be asked to do in the study: To participate in an individual interview led by a graduate student. Some sample questions that you may be asked are,

1. What does the word, “making,” mean to you?
2. What role do you believe making plays in the Navajo culture?
3. How does engineering affect your daily life?

Collection of Data: The interview will be audio recorded and transcribed. Transcription may be conducted by an external transcription service. The principal investigator, researchers from Tufts University, researchers from the Navajo Nation community, and the Navajo Nation will have access to the collected data. The data will become part of collections and may be maintained or archived indefinitely by the Navajo Nation. Within one year of the date that the data is collected, all other copies of the data not owned by the Navajo Nation will be deleted.

Benefits: While there are no direct benefits for the participants, the data collected may have significance for future practice, research, and policy.

Compensation: There is no compensation for participating in this study.

Confidentiality: Your identity will be kept confidential to the extent provided by law. The names of the participants will not be used in any research reports or presentations. Your name will not be connected to your responses once our interview is over. The finals results may be sent to research journals or magazines for possible publication or used in research conference presentations as well as Ph.D. dissertations.

Potential Conflict of Interest:
The P.I., Daniel Frank, is teaching a graded course at Navajo Technical University as a volunteer (not paid by Navajo Technical University) as well as helping several students on their projects. It may be possible that some of the students that the P.I. is working with/teaching outside of this project may wish to participate in the study. To mitigate any possible conflicts of interest, the study is completely voluntary and will have no effect on them regardless if they decide to participate or not.

Whom to contact about your rights as a research participant in the study:
Beverly Becenti-Pigman, Board Chair, Navajo IRB Office. Navajo Department of Health, P.O. Box 1390, Window Rock, AZ 86515; ph 928-871-6829 or fax 928-871-6255

UFIRB Office, Box 112250, University of Florida, Gainesville, FL 32611-2250; ph 352-392-0433.

UF Study ID: IRB201600888
Voluntary participation: Your participation in this study is completely voluntary. There is no penalty for not participating and it shall not interfere with services available to the rest of the population.

Right to withdraw from the study: You have the right to withdraw from the study at any time without consequence. You do not have to answer engage any activities that you do not want to.

Risks: This study will only involve no more than minimal physical or psychological risks or discomforts for the participants that may result from participation in this research project.

I have read the procedure outlined above. I voluntarily agree to participate in this study and have received a copy of this description.

Participant’s signature and date

Principal investigator’s signature and date

[Signature]

This consent document is approved for use until: July 19, 2017

UF Study ID:IRB201600888
APPENDIX G
INTERVIEW PROTOCOL

Overview:

1) Tell me a little about yourself.
   a. Age?
   b. Ethnic background?

Making:

2) What does the word, “making,” mean to you?

3) Do you consider yourself a maker?
   Yes
   a. Describe what makes you a maker?
      i. How did you learn?
      ii. How did you develop your skills?
      iii. What was your motivation (making a living, spiritual, for fun, etc.)?
   b. Describe what it means to you when you make something.
      i. Describe the context of when you make, location, frame of mind, etc.

   No
   c. Who do you perceive as being a maker?

4) What role do you believe making plays in the Navajo culture?

5) What are examples of making that you have seen in the Navajo culture?

6) Describe your understanding of engineering?

7) How does engineering affect your daily life?
   a. What are some types of engineering problems you would like to solve?

8) What do you see as the relationship between making and engineering?

Wrap-Up:

9) Is there anything else you would like to add?
LIST OF REFERENCES


Dougherty, D. (2011). We are makers [Video File]. Retrieved from https://www.ted.com/talks/dale_dougherty_we_are_makers#t-28917


BIOGRAPHICAL SKETCH

Daniel Z. Frank was born and raised on the New Jersey-Pennsylvania border. As an undergraduate, he attended Lehigh University from which he graduated summa cum laude in May 2009, earning his Bachelor of Science degree in mechanical engineering. For the 2010-2011 school year, he taught mathematics and coached soccer for middle school students from the Navajo Nation. While working with these students, he was inspired to start an engineering club after school. The success of this club helped him develop his passion for promoting engineering education and outreach for Native American communities. In August 2011, he enrolled in the University of Florida for graduate school. There, he earned his Master of Science degree in mechanical engineering in December 2012. He then began his Doctor of Philosophy degree working at the Center for Intelligent Machines and Robotics. During his time at the University of Florida, he won two international autonomous surface vehicle competitions with the Machine Intelligence Lab, helped found the STEM outreach student organization known as BOTS (Building Others Through STEM), mentored local FRC Team 4118: Roaring Riptide, supported the assistive technology field through adapting toys and Power Wheels cars, and promoted engineering education for Native American students in the states of Arizona, New Mexico, and Oklahoma. He received his Doctor of Philosophy degree in mechanical engineering in May 2018.