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A Sociocultural Analysis of Latino High School Students' Funds of Knowledge and Implications for Culturally Responsive Engineering Education

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A SOCIOCULTURAL ANALYSIS OF LATINO HIGH SCHOOL STUDENTS' FUNDS OF KNOWLEDGE AND IMPLICATIONS FOR CULTURALLY RESPONSIVE ENGINEERING EDUCATION

by

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ABSTRACT

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by

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The purpose of this study was to investigate the funds of knowledge of Latino and Latina high school adolescents, and how they used their funds of knowledge to solve engineering design problems in their communities. This study was based on the assumption that creating a bridge between different formal resources (e.g., engineering design processes) and informal resources (e.g., funds of knowledge) is an important step toward encouraging Latino and Latina high school adolescents to enter and remain in the field of engineering. The intent of this study was to generate a framework of funds of knowledge that teachers can draw from in order to create culturally responsive high school engineering instruction that connects adolescents' out-of-school practices to the formal practices of engineering.

An ethnographic approach was used to investigate the funds of knowledge of fourteen Latino and Latina high school adolescents. The participants were selected from a rural community located in the Western United States. They were divided into four different groups and each group selected a problem in their community that was of interest to them. Each group met twice per month and every student was interviewed every month individually. For this study, data sources included participant responses to individual interviews, observations of group discussions, retrospective and concurrent protocols, and participant-generated products.

A constant comparative analysis showed that the participants possessed an understanding of societal, environmental, technical, and other engineering-related practices, dispositions, and habits of mind, which helped them to engage in engineering design in a holistic way. The study suggested that Latino and Latina adolescents, although profoundly underrepresented in engineering, bring a wealth of knowledge and experiences that are relevant to engineering design thinking and practice.

(240 pages)

PUBLIC ABSTRACT

A Sociocultural Analysis of Latino High School Students' Funds of Knowledge and Implications for Culturally Responsive Engineering Education

Joel Alejandro Mejia

Previous studies have suggested that, when funds of knowledge are incorporated into science and mathematics curricula, students are more engaged and often develop richer understandings of scientific concepts. While there has been a growing body of research addressing how teachers may integrate students' linguistic, social, and cultural practices with science and mathematics instruction, very little research has been conducted on how the same can be accomplished with Latino and Latina students in engineering. The purpose of this study was to address this gap in the literature by investigating how fourteen Latino and Latina high school adolescents used their funds of knowledge to address engineering design challenges. This project was intended to enhance the educational experience of underrepresented minorities whose social and cultural practices have been traditionally undervalued in schools.

This ethnographic study investigated the funds of knowledge of fourteen Latino and Latina high school adolescents and how they used these funds of knowledge in engineering design. Participant observation, bi-monthly group discussion, retrospective and concurrent protocols, and monthly one-on-one interviews were conducted during the study. A constant comparative analysis suggested that Latino and Latina adolescents, although profoundly underrepresented in engineering, bring a wealth of knowledge and experiences that are relevant to engineering design thinking and practice.

DEDICATION

Dedico este trabajo a mi madre y a mi padre que gracias a ellos estoy aquí en este mundo tratando de hacerlo mejor cada día. A mis hermanos, Sergio y Manuel, y mi hermana, Magaly, que a pesar de la distancia sé que estoy siempre en sus oraciones. A mi familia de El Paso – Angelina, Pepe, Luis, Angélica, Lupita – porque siempre han estado al pendiente de mi. Este trabajo también está dedicado a mis primas Lila, Meche, Viviana, y Blasa que siempre me apoyan en todo lo que hago. Lila y Viviana ustedes son mi ejemplo a seguir y me han enseñado a luchar por mis convicciones. A toda mi familia por sus palabras de aliento para seguir adelante y por su soporte moral, paciencia, y comprensión durante este camino que he decidido recorrer.

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I also dedicate this work to the adolescents who participated in this project. I appreciate your willingness to work with me throughout this fantastic journey. You are amazing and taught me a great deal about life. Move forward, believe in yourselves, aim high, and cherish and preserve the cultural and ethnic diversity that strengthens this nation. ¡Hasta la victoria siempre!

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Joel Alejandro Mejia

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CHAPTER 1

INTRODUCTION

One major challenge for engineering education is the underrepresentation of minority students as stakeholders seek to diversify the field (National Science Board, 2014). Particularly, Latino underrepresentation in engineering is a subject of ongoing concern in the United States. Although Latinos are one of the fastest growing ethnolinguistic groups in the country (U.S. Census Bureau, 2012), research (National Academy of Engineering and National Research Council, 2009) indicates that careers in engineering and science are dominated by individuals whose background is White, English-speaking, and middle class. Even though the Latino population has increased and continues to influence the labor force of the country, the number of Latinos receiving degrees in either science or engineering remains stagnant (Lichtenstein, Chen, Smith, & Maldonado, 2014). Overall, Latino students encounter greater difficulties in obtaining science, technology, mathematics, and engineering (STEM) degrees and typically take longer to graduate than their Caucasian peers (Slovacek et al., 2011).

Studies have tried to explain the inaccessibility of science and engineering for underrepresented minorities on the basis of institutional factors. Johnson, Brown, Carlone, and Cuevas (2011) indicated that institutionalized inequities and prejudices may actively work to drive people of color out of science and engineering fields. Other scholars (P. Barton, 2003; Carter, 2006; Chapa & De La Rosa, 2006) have attributed Latino underrepresentation in STEM to the lack of student engagement, misconstrued perceptions toward Latinos, and the lacking presence of Latino engineers as role models. In addition to these institutionalized factors that contribute to the lack of attention given to students of color at the K-12 level, other research has suggested that K-12 teachers hold the "general perception that Latinos cannot advance through the pipeline" (Rochin & Mello, 2007, p. 306).

As suggested by this research, Latinos face challenges as they try to pursue degrees in STEM fields including the presence of leaks in the educational "pipeline." The term "pipeline" has been used as a metaphor to describe the national educational landscape and the challenges students face in order to succeed in the educational system. In this metaphor, the pipeline is sometimes framed by national policy and different assumptions that dictate who is capable of following a successful academic trajectory (Lyon, Jafri, & St. Louis, 2012). From a conceptual standpoint, the pipeline can be seen as a series of successive transitions starting from graduation from high school, entry into higher education, persistence in higher education, and completing a college degree (Ewell, Jones, & Kelly, 2003). The achievement of Latino students in STEM fields is related to the different issues in the educational pipeline such as underpreparation of Latino students in K-12 and the number of Latino students in higher education who could pave the way for others (Rochin & Mello, 2007). Thus, success depends on the starting point of the transitions in the pipeline: graduation from high school with an interest in STEM topics.

Although different scholars have offered several reasons behind why Latino students do not pursue STEM careers, many scholars have argued that one particularly powerful reason is that the cultures of underrepresented students do not fit with the "cultures of engineering" (Stevens, O'Connor, Garrison, Jocuns, & Amos, 2008). Stevens et al. (2008) emphasized the importance of "identification with and by engineering" in order to succeed in the field (p. 365). However, it may be difficult for Latino students to identify with engineering due to their unfamiliarity with the discipline. The National Academy of Engineering and National Research Council (2009) argued that in engineering education "curricular materials do not portray engineering in ways that seem likely to excite the interests of students from a variety of ethnic and cultural backgrounds" (p. 10), perhaps because educators do not understand how engineering relates to the social, cultural, or historical contexts in which the students live (Wertsch, 1998). Nonetheless, Latino students deserve substantive, quality opportunities to connect with engineering.

The "cultures of engineering" concept (Stevens et al., 2008) can be related to the "cultural border crossings" mentioned in other studies concerning science education and underrepresented minorities. Aikenhead and Jegede (1999) described minority students' conflicts when they move between two different worlds, the world of science and the world of their everyday lives. The social practices, languages, and everyday knowledge students have at home are often foreign to science, creating a "cultural border crossing" that may affect their learning. As Lee (1999) stated, "From the sociocultural perspective, learning science involves learning to think, talk, and act as a member of the science community. It also involves developing the values and beliefs shared in the science community" (p. 189). Unfortunately, underrepresented minorities, including Latinos, often do not identify with engineering or do not see the connections between engineering and science and their own personal interests, values, or social and cultural practices. The lack of connections between the students' everyday life world and the science world builds a type of "cultural border crossing" that suggests the existence of two separate entities (Aikenhead & Jegede, 1999, p. 269). This separation creates a feeling of marginalization for underrepresented students.

In an effort to create a bridge between underrepresented students' everyday lives and formal instruction in the science classroom, relevant work in K-12 science and mathematics has been done regarding the study of household funds of knowledge and formal bodies of knowledge learned in school (Barton & Tan, 2009; Civil, 2002; Martin, 2006; Moje et al., 2004). Authors (Gonzalez, Moll, & Amanti, 2005; Moll, Amanti, Neff, & Gonzalez, 1992; Velez-Ibañez & Greenberg, 1992) have used the term *funds of knowledge* to describe the different bodies of cultural knowledge and skills associated with different communities. These studies have observed the potential of bridging science classroom practices and funds of knowledge to create deeper and more meaningful learning for underrepresented populations. The argument is that through open dialogue with the students, the instructor gains insight to the cultural and epistemological perspectives of the students, resulting in cross-cultural exchanges of ideas.

Although previous research has explored Latino students' funds of knowledge in K-12 science and mathematics, comparable research has not been done in the field of engineering education. However, the same theoretical frameworks apply to the need for culturally responsive K-12 engineering education initiatives. The importance of engineering education at the K-12 level has gained national attention in the past few years. The number of engineering education curricula has increased across the United States (National Academy of Engineering and National Research Council, 2009). Moreover, efforts are currently in place to develop an understanding of science through engineering activities among high school students. The release of the Next Generation

Science Standards (NGSS) (Achieve Inc., 2013) coincides with the strong belief that science education is vital to the United States' ability to compete with the rest of the world. The NGSS has taken on the initiative to implement science learning through engineering crosscutting practices, including engineering design activities.

Although K-12 engineering education is becoming more popular nationally, little research exists on how to make engineering appealing to high school students who are minorities. Therefore, this study represents an important contribution to existing literature. This research builds on existing sociocultural research in engineering education, funds of knowledge, and engineering design. Based on the idea that engineering involves different cultural dimensions (Godfrey & Parker, 2010) and that engineering design is a central part of engineering (Dym, Agogino, Eris, Frey, & Leifer, 2005), this study highlights the social and cultural contexts of Latino adolescents as they engaged in engineering design by investigating the funds of knowledge of Latino high school students.

Problem Statement

From a sociocultural perspective, the ways of knowing, doing, the values, and practices of a particular culture shape the learning, behavior, and identity of individuals (Aikenhead & Jegede, 1999; Gay, 1992). This exploratory study is based on the assumption that creating a bridge between different formal resources (engineering design processes) and informal resources (funds of knowledge) is an important step toward encouraging Latino high school students to enter and remain in the field of engineering. The purpose of this study was to investigate the funds of knowledge of a group of Latino high school students and how they use their funds of knowledge to solve engineering design challenges. The study focuses on how Latino students use and apply relevant funds of knowledge to the engineering design process, how the funds of knowledge in Latino communities can be connected to engineering design, and how to identify those funds of knowledge that are not traditionally valued in schools in an effort to provide culturally responsive engineering instruction to Latinos.

Research Questions

In order to build the long-term success of Latinos in STEM education, it is important to understand Latino high school students' funds of knowledge and ways of learning. The use of engineering design activities can help the learning outcomes of Latino students, particularly in the context of ill-structured problems (Jonassen, 1997, 2000, 2014; Newell & Simon, 1972), or problems that do not yield a pre-determined answer or that mirror real-world problems, while relating concepts to their own background and prior knowledge. However, few studies have documented how funds of knowledge present in Latino communities are related to engineering design challenges. Therefore, it is important to conduct in-depth ethnographic studies with Latino high school students to document their funds of knowledge, and to learn how these informal resources are connected to more formal engineering design practices in order to advance engineering instruction for Latino students at the K-12 level. This exploratory study intends to answer two different questions:

1. What engineering-related funds of knowledge do Latino high school students have?

2. How are these funds of knowledge used to address a self-selected community-based engineering design problem?

In order to address these questions, I draw from sociocultural frameworks to emphasize the importance of understanding students' ways of knowing and doing. The first is a sociocultural perspective of student learning as an intrinsic and inseparable aspect of social practices (Vygotsky, 1978). The second is a *funds of knowledge* framework to emphasize the importance of understanding students' ways of knowing, doing, and thinking in order to provide a well-situated sociocultural view of engineering (Tonso, 2014). The following section includes a definition of terms associated with these frameworks.

Definition of Terms

Beliefs: "Individual's judgment of the truth or falsity of a proposition, a judgment that can be only inferred from a collective understanding of what human beings say, intend, and do" (Pajares, 1992, p. 316).

Body of knowledge: Collective knowledge formed by a set of concepts learned by practice and/or observation.

Communicative validation: Implies validation of interpretative research by asking participants to provide feedback on the findings and corroborate the data (Walther, Sochacka, & Kellam, 2013).

Community-based engineering design challenge: Engineering experiences where individuals research, analyze, and/or design solutions to problems affecting their community.

Concurrent protocols: Type of verbal report where the cognitive processes, described as successive states of heeded information, are verbalized directly ("talk aloud" and "think aloud" reports) (Ericsson & Simon, 1993; Smagorinsky, 1994).

Confianza: A form or mutual reciprocity where both parties recognize and honor the familiarity and trust in their relationship (Gonzalez et al., 2005).

Constant comparative analysis: Method consisting of identifying a phenomenon, object, or event, then comparing incidents applicable to each category, and finally integrating such categories and their properties. This method combines category coding with simultaneous comparison of all incidents observed as well as simultaneous comparison across categories (Corbin & Strauss, 2014).

Culture: The accumulation of knowledge, experience, beliefs, values, attitudes, and relations acquired by a group in the course of generations through individual and group striving (Aikenhead, 1996; Aikenhead & Jegede, 1999).

Cultural border crossing: Term that describes students crossing from the subculture of their peers and family into the subcultures of science and school science (Aikenhead, 1996; Giroux, 1992).

Culturally responsive education: Model that recognizes that students learn in different ways, and focuses on the learning strengths of the students while mediating the frequent mismatch between home and school cultures (Paris, 2012).

Deficit thinking: Refers to the notion that students (particularly low-income, minority students) fail in school because such students and their families experience deficiencies that obstruct the learning process (e.g. limited intelligence, lack of motivation, and inadequate home socialization) (Valencia, 1997).

Discourse: The ways of using language, of thinking, valuing, acting, and interacting used to identify oneself as a member of a socially meaningful group or social network (Gee, 2008).

Dominant culture: Refers to the group that exercises and holds the most power or influence on the beliefs, values, perceptions, communication patterns, and customs of a group. This group of individuals possess the instruments of power that allow them have cultural domination (Kincheloe & McLaren, 2000; Samovar, Porter, McDaniel, & Roy, 2013).

Engineering design: "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" (Dym et al., 2005, p. 104).

Ethnicity: Characteristic of a group of people sharing common and distinctive racial, religious, linguistic, or cultural heritage maintained by boundaries in order to explain their own identity (Barth, 1998).

Ethnography: A social scientific description and interpretation of a cultural or social group or system (Creswell, 2012; Vidich & Lyman, 2000).

Funds of knowledge: The historically accumulated and culturally developed bodies of knowledge and skills essential for household or individual functioning and well-being (Gonzalez et al., 2005; Velez-Ibañez & Greenberg, 1992).

Language: System of communication used by a particular community.

Latinos: Term used in the United States to refer to both males and females of Latin American descent (U.S. Census Bureau, 2012).

Microculture: Refers to the group in a society (subset) that exists within the dominant culture, and that lives differently from the dominant culture (Aikenhead, 1996; Aikenhead & Jegede, 1999).

Non-dominant culture: Refers to the group that remains on the margins of society and is generally unable to impose its values, language, and ways of behaving (Samovar et al., 2013).

Norms: A pattern, principle, or function that is usual, typical, or standard.

Practices: Socially recognized and institutionally or culturally supported endeavor that usually involves sequencing or combining actions in certain specified ways (Gonzalez et al., 2005).

Pragmatic validation: Implies validation of interpretative research by gathering data in a "natural setting" (Walther et al., 2013).

Procedural validation: Implies validation of interpretative research by asking questions (interview protocols) that focus on eliciting specific and different ways of cross-checking coding categories (Walther et al., 2013).

Purposeful sampling: The process of selecting cases that are likely to be "information-rich" with respect to the purposes of a qualitative research study (Gall, Gall, & Borg, 2007).

Retrospective protocols: Type of verbal report where the participant is prompted to reconstruct a process or task from memory. Retrospective reports based on information in Long Term Memory (LTM) require additional process of retrieval (Ericsson & Simon, 1993; Smagorinsky, 1994).

Theoretical validation: Implies validation of interpretative research through different data sources in order to capture multiple perspectives (Walther et al., 2013).

Underrepresented minorities: Any ethnic group whose representation is disproportionately less than their proportion in the general public (U.S. Census Bureau, 2012).

Values: The important or lasting beliefs or ideals shared by members of a culture about what is good or bad, desirable or undesirable.

Overview of Methodology

In order to build the bridge connecting engineering design processes to the everyday lives of students, I sought to construct a framework outlining the funds of knowledge that are relevant to engineering design. This methodology requires a qualitative approach that allows for contextual descriptions of the phenomenon taking place (Borrego, Douglas, & Amelink, 2009). This study relied on a qualitative research methodology and used ethnographic techniques, such as interviewing and observations, in order to collect data that revealed the students' funds of knowledge. Throughout the study, data were collected from individual interviews, observations, group discussions, concurrent and retrospective protocols, and students' artifacts.

Fourteen adolescents (ages 14-17) were purposively selected to participate in the study based on four criteria: (a) self-identify as Latino, (b) be enrolled in high school, (c) speak Spanish at home, and (d) receive or had received English as a second language (ESL) services for a prolonged period of time. Prospective participants were interviewed for 30 minutes to determine whether they met the selection criteria. One of the original fourteen participants left the study because of immigration issues. However, she was replaced by another participant who had previously showed interest in participating in the project and was considered as a strong candidate to participate during the initial selection process.

All interview questions were open-ended and intended to elicit information about the participants' funds of knowledge. The data were analyzed using the theoretical lens of *funds of knowledge* (Gonzalez et al., 2005; Moll et al., 1992), which described the bodies of knowledge, skills, and practices present in the students' households and communities. *Funds of knowledge* was used as the "lens through which the findings were interpreted" (Borrego et al., 2009, p. 57). This lens provided a rich contextual description of the social and cultural situated engineering-related practices of the Latino students in this study.

Assumptions of the Study

It is assumed that engineering design is not a strictly cognitive activity that is separate from relationships, material worlds, cultures, and everyday experiences. Engineering in this study is seen as a type of Discourse, which Gee (2008) defined as the following:

> [A Discourse] is composed of distinctive ways of speaking/listening and often, too, writing/reading coupled with distinctive ways of acting, interacting, valuing, feeling, dressing, thinking, believing, with other people and various objects, tools, and technologies, so as to enact specific socially recognizable identities engaged in socially recognizable activities. (p. 155)

In accordance with this definition, engineering design processes are the enactment of a larger engineering Discourse. According to Godfrey and Parker (2010), there are values, beliefs, and assumptions that align with the norms of engineering, creating the engineering Discourse. Engineering is not exclusively a cognitive process but it is embedded within Discourses, which include a set of social practices and tools.

It is also assumed that funds of knowledge and Discourses are inherently social and constructed in and through relationships. Depending on their home or school experiences and their acquired ways of knowing, thinking, doing, writing, communicating, or use of tools, Latino students' everyday Discourses may share commonalities with engineering Discourses.

Limitations of the Study

It cannot be assumed that all Latino adolescents possess the same funds of knowledge as the participants in this study. Also, the study does not imply that only Latino adolescents possess funds of knowledge. In fact, everyone has funds of knowledge, but the purpose of this study was to investigate the funds of knowledge of Latino adolescents because they are underrepresented in engineering. By analyzing their out-of-school practices, this study sought to identify ways in which these practices could be used as a bridge to the formal practices of engineering.

Another limitation is that, although all Latino adolescents possess funds of knowledge, they may not always apply their funds of knowledge to solve engineering design problems. Thus, the adolescents may have possessed funds of knowledge that were not discernible in this study. In addition, it was not the intent of this study to evaluate the students' final products but to analyze their funds of knowledge. This study does not suggest that the final solutions or products approximated the solutions of professional engineers.

It is important to emphasize that the framework obtained from this study, as with any other qualitative approach, is not generalizable. However, the framework obtained from the study could be transferable to K-12 classroom settings as engineering teachers reflect on how their students might consider funds of knowledge that are similar to those outlined in this study (Borrego et al., 2009). The framework of funds of knowledge would allow "readers to identify elements that can be transferred to their own situations" (Borrego et al., 2009, p. 57).

Significance of the Study

Like other studies involving funds of knowledge and science (Barton & Tan, 2009; Moje et al., 2004) and mathematics education (Civil, 2002; Razfar, 2012), this study involves working with minority students using interpretive research. Interpretive research is relevant and significant to the field of engineering education (Walther et al., 2013). According to Case and Light (2011), including these methodologies is important for the growing field of research in engineering education. Innovative pedagogies will only be implemented if they are grounded in a broad range of research methodologies (Case & Light, 2011).

This study does not imply that only Latinos or students of color have rich funds of knowledge emerging from social and cultural experiences. However, school knowledge and Discourses tend to be aligned with the knowledge and Discourses of the dominant culture (Bourdieu & Passeron, 1990; Moje et al., 2004). Therefore, this project is intended to provide an insight on how to bring culturally responsive practices into engineering education, and to enhance the educational experience of underrepresented minorities whose social and cultural practices have been traditionally undervalued in schools. In addition, it is the intent of this study to generate a framework of funds of knowledge that teachers can draw from and create culturally responsive high school engineering instruction that connects adolescents' out-of-school practices to the formal practices of engineering.

CHAPTER 2

LITERATURE REVIEW

Navigating the cultures of engineering can be difficult for underrepresented minorities. Students are required to go through a series of institutional passage points in order to become an engineer, including the possession of disciplinary knowledge where only certain types of knowledge are valued (Stevens et al., 2008). Acquiring disciplinary knowledge can be considered one component of the dimensions of the culture of engineering categorized as “the engineering way of thinking” (Godfrey & Parker, 2010, p. 9). Godfrey and Parker (2010) suggested that in engineering certain types of knowledge are valued and that different engineering “subcultures” show a prevalent engineering “way of thinking,” “way of doing,” and the “engineering identity.”

The engineering way of thinking and doing may contradict the ways of knowing and doing of underrepresented students whose behaviors and cultural norms are opposite to those encountered in institutional structures related to engineering. The knowledge and understandings of underrepresented students may be in conflict with the cultural norms of engineering education and the engineering profession (Foor, Walden, & Trytten, 2007). In fact, underrepresented students may go through a process of enculturation where they may be forced to adapt to, or adopt, the cultural norms of engineering (Tonso, 1996). Latino students’ prior experiences and own world views may conflict with engineering norms, making it difficult for them to navigate engineering and/or identify with engineering-related practices. Tonso (1996) argued that “engineering education, as one facet of engineering culture, is not simply training in a prescribed set of appropriate, academic courses, but is enculturation into a well-established system of practices, meanings, and beliefs" (p. 218). This enculturation requires adaptation from others. Similarly, Latino students may be required to adapt to engineering cultural norms that could be detrimental to them in the sense that it requires them to act in way that run counter to their home cultures. For this reason, it is necessary to find common ground for Latino students in order to help them navigate and engage in engineering.

The lack of academic achievement and engagement of Latinos in engineering is a problem emerging from this conflict between students' cultures and the cultures of engineering (Riley, Slaton, & Pawley, 2014). Although there are many factors affecting underrepresentation of Latinos in engineering, this study does not attempt to explain all those factors. This study aims to investigate the historically developed and accumulated strategies or bodies of knowledge, also known as funds of knowledge (Moll et al., 1992), of Latino students as they solve a community-based problem. This analysis would help determine how Latino students' funds of knowledge bear connections to formal engineering norms.

I argue that engineering can be seen as a type of Discourse, with a capital D, which Gee (2008) described as

> distinctive ways of speaking/listening and often, too, writing/reading coupled with distinctive ways of acting, interacting, valuing, feeling, dressing, thinking, believing, with other people and with various objects, tools, and technologies, so as to enact specific socially recognizable identities engaged in specific socially recognizable activities. (p. 155)

Our Discourse gives us our sense of self, what we do, and how we act every day. Discourses are socially situated identities and highly influence the social context in which knowledge and certain practices materialize. Thus, Discourses influence how individuals practice and engage in different activities, including engineering. Based on Gee's (2008) definition of Discourse, engineering design can be described not only as a cognitive process but also as part of a larger engineering Discourse that is not separated from the cultural and social dimensions of engineering.

Similarly, depending on their experiences at home, in their community, or with peers, underrepresented students acquire ways of knowing, doing, and thinking that allow them to navigate through their everyday lives (Aikenhead & Jegede, 1999). Unfortunately, creating a bridge between the students' cultural worldviews and engineering Discourse is complicated, thus leading to a problematical cultural border crossing. The cultural border crossing is created when the norms, values, beliefs, or actions of the individual do not align with those norms, values, beliefs, or actions of the scientific community (Aikenhead & Jegede, 1999).

It is important to examine students' out-of-school experiences in order to create a bridge that aligns their cultural worldviews with engineering Discourses. The Next Generation Science Standards (Achieve Inc., 2013) emphasized the importance of relating STEM instruction to students' interests and experiences in order to improve the readiness of underrepresented high school students in the United States. To make engineering education more inclusive and diverse, educators can address the problem of lacking diversity and inclusiveness in engineering by viewing social, cultural, and linguistic activity as relevant to engineering design processes (National Steering Committee of the National Engineering Education Research Colloquies, 2006).

This chapter synthesizes the current literature related to engineering cultures, everyday cultures of students, cultural border crossings, and engineering design. This review of literature also builds a set of theoretical frameworks based on research related to funds of knowledge and its applicability to engineering education at the K-12 level. This review also emphasizes the importance of understanding Latino youths' ways of knowing, doing, and thinking in order to provide a well-situated sociocultural view of engineering design.

Engineering Cultural Dimensions

It has been argued that without an understanding of culture and the impact of culture in education, student learning is likely to be ineffective (Kruse & Louis, 2009). The notion of "culture" in engineering education literature is a relatively new concept. Godfrey and Parker (2010) indicated that although there has been extensive educational research on the impact of culture in other fields, engineering education culture has not been defined and most of the research regarding engineering culture has been done by someone outside of the engineering education community. To this date, most of the research in engineering education has not been characterized by robust ethnographic research, and "most of the ethnographic research has been based on the lack of women in engineering" (Godfrey & Parker, 2010, p. 5). The research done regarding perspectives on the culture of assessment in engineering (Borrego, 2008; Lattuca, Terenzini, & Volkwein, 2006), women underrepresentation and enculturation (Godfrey, 2004, 2007; Tonso, 1996), engineering identity (Meyers, Ohland, Pawley, Siliman, & Smith, 2012; Pawley, 2009; Stevens et al., 2008; Tonso, 1996), or campus culture (Tonso, 2006) has not attempted to provide a map that would move toward cultural change at the K-12 level.

In an effort to move toward the development of a cultural map and cultural change at the college level, Godfrey and Parker (2010) conducted case studies that described the engineering education culture. The study identified six “cultural dimensions,” which included (a) an engineering way of thinking, (b) an engineering way of doing, (c) being an engineer, (d) acceptance of difference, (e) relationships, and (f) relationships to the environment (Godfrey & Parker, 2010, p. 9). These cultural dimensions provided “a holistic framework to group the values, beliefs, and assumptions which underpin the culture of engineering education at the disciplinary, departmental, or institutional level” (Godfrey & Parker, 2010, p. 18). This section describes the six cultural dimensions of engineering.

Engineering Way of Thinking

The “engineering way of thinking*”* described the “unique ways of knowing and thinking relevant to engineering” (Godfrey & Parker, 2010, p. 9). The study indicated that contextual scientific and mathematical learning was highly valued in engineering by both faculty and students. There was a consensus that “engineering dealt with a tangible, definable, measurable, quantifiable reality” (Godfrey & Parker, 2010, p. 9). Mathematics, modeling, and problem solving played a significant role in the engineering curriculum. Instead of using mathematics as a tool, for some students mathematics became a communication method. In addition, faculty and students assumed that the application of scientific and mathematical principles must yield a solution, and that based on those principles any solution should work (Godfrey & Parker, 2010). Scientific and mathematical knowledge were regarded as an essential component of engineering and the "key to access understanding and thinking like an engineer" (Godfrey & Parker, 2010, p. 10). In fact, scientific and mathematical knowledge were given preferential treatment and counted as engineering knowledge.

According to Riley et al. (2014), classical philosophical engineering education tends to situate the engineering ways of thinking as objective, methodological, and technical. However, deciding what constitutes engineering can also exclude other ways of thinking that can also be considered engineering. Because of the influence of these individuals on the decision-making process of what constitutes engineering, those who have constructed engineering as a discipline have also, directly or indirectly, decided who becomes an engineer (Riley et al., 2014). An ethnocentric, male-dominated, engineering way of thinking has permeated through the engineering discipline (Tonso, 1996; Walker, 2001). Downey and Lucena (2005) argued that "what counts as engineering and engineering knowledge has varied over time and from place to place" (p. 252). Despite the variation, the content and practice of engineering has largely been established by white men who have eventually decided what is "engineering" (Riley et al., 2014).

Similarly, Stevens et al. (2008) argued that engineering education favors "accountable disciplinary knowledge" – the actions that count as engineering knowledge (p. 357). "Accountable disciplinary knowledge" falls within the same category of the "engineering way of thinking," where students are expected to display scientific and mathematical abilities or provide correct answers to well-defined problems. The "engineering way of thinking," which is institutionalized in undergraduate engineering programs, assumes that technical and scientific knowledge are the only sources of knowledge (Godfrey, 2014; Godfrey & Parker, 2010), while the reality may be different in practice. Engineering education faculty and students often assume that alternative ways of knowing and the "engineering way of thinking" are mutually exclusive.

Engineering Way of Doing

The "engineering way of doing" described the "shared beliefs an assumptions around how teaching and learning was accomplished in engineering" (Godfrey & Parker, 2010, p. 12). The study indicated that most of the students perceived engineering as a challenging program due to the heavy workload and the content of the curriculum. According to the students, learning engineering involved taking difficult courses and success was measured by the students' ability to endure the workload. Those who completed their degree felt "more worthy" for completing a degree that was "hard" because "anything worthwhile was difficult" (p. 12). Only those who were willing to work extremely hard accomplished the goal of becoming engineers.

Stevens, Amos, Jocuns, and Garrison (2007) argued that engineering students have the perception that an engineer's worth is measured by the amount of "hard" work they perform. Because there is the belief that engineers work harder than other people, there is also the assumption that only those who can perform belong in engineering. This belief is similar to the "weed out" system described by Seymour and Hewitt (1997), where those students incapable of performing the hard work were forced out of engineering programs regardless of academic preparation. It is implied that advancement in the engineering program is only achievable through intellectual or educational merit. Thus, meritocracy plays an important role in the "engineering way of doing" because it establishes who is worthy of becoming an engineer (Foor et al., 2007; Stevens et al., 2007).

The “engineering way of doing” does not include “easy” courses that incorporate discussions and subjective interpretations of content. According to Godfrey (2014), engineering education programs emphasize the essential content that needs to be covered and the appropriate instructional methods used, such as lecturing. In engineering programs, successful students differentiate between the “hard” and “soft” courses, where preference was given to the “hard” courses that included more technical content (Godfrey & Parker, 2010). According to Godfrey (2014), “much of this ‘essential content’ continues to be taught internationally through traditional, lecture-based courses and is seen as the fundamental knowledge that distinguishes engineers as experts in their field” (p. 442). Unfortunately, the “engineering way of doing” has created the beliefs and assumptions that engineering is an area of study that is reserved only for those who will endure the “hard” courses. Students who are not willing to endure hard lecture-based courses will often not pursue careers in engineering (Matusovich, Streveler, & Miller, 2010).

Being an Engineer

Godfrey and Parker (2010) also named engineering identity as another important cultural dimension. Godfrey and Parker (2010) indicated that the beliefs and assumptions about the attributes of an engineer were a key factor when creating an engineering identity and “being an engineer” (p. 14). The qualities of “being an engineer” determined who fit in and who would be successful in engineering (Godfrey & Parker, 2010; Stevens, O’Connor, & Garrison, 2005). One of the qualities of an engineer, as perceived by faculty and students, was the scientific and mathematical competency of the individual. Some of the attributes that described engineers included being logical, practical, conservative, pragmatic, and not emotionally demonstrative (Godfrey & Parker, 2010). Engineers are also identified as individuals that make things, apply science and math, and problem solvers (Pawley, 2009). Self-identifying with these qualities was an indicator of becoming an engineer. In fact, those students that self-identify as engineers are more persistent in their engineering programs (Meyers et al., 2012).

Acceptance by other engineering students also creates a sense of self-identification with engineering, while not being accepted as part of the engineering community can jeopardize the students' retention in engineering. Stevens et al. (2008) argued that it was not until the students were accepted into the engineering programs that they were perceived as being engineers, thus increasing solidarity with others. Becoming an engineer involved not only self-identifying as an engineer but also being perceived by others as an engineer. Unfortunately, professors and fellow college students often do not identify students of color as being potential engineers (McGee & Martin, 2011).

For these reasons, creating an engineering identity for some students may be daunting. Tonso (2014) argued that the lack of identification with engineering motivated students to leave engineering and pursue other degrees. Tonso (1996) indicated that in order to fit in, underrepresented students, particularly women, "must appear to accept the existing norms and not openly resist or challenge them" (p. 224). However, identifying with an engineering community may be significantly more difficult for underrepresented students. For example, female students must tolerate and adhere to the particular male norms already established in engineering in order to be considered worthy of becoming an engineer (Tonso, 1996, 2006). These norms include being practical and technical, being tough, and engaging in social interactions or social relations that are assumed to be part of the engineering identity (Tonso, 1996). Female students and female faculty have to accept the existing male norms and endure the ordeals imposed by men or those within the dominant culture (Foor et al., 2007; Tonso, 1996). The problem is that diverse viewpoints are not respected and challenging these norms can be counter-productive. Because underrepresented students are subject to predetermined engineering norms, students do not get a chance to form engineering identities that recognize their diversity.

Acceptance of Difference

The beliefs and assumptions regarding homogeneity in engineering education have the potential of affecting the culture of engineering and therefore the “acceptance of difference” (Godfrey, 2014). A high degree of homogeneity exists within engineering (Godfrey & Parker, 2010), leading to rigid and hegemonic values, beliefs, and assumptions adopted in engineering and by engineering faculty and students. The assumption is that faculty and students share the same set of values and beliefs, leaving no room for discussion of other worldviews or opinions that challenge the existing engineering norms. There is little consideration of how institutional practices affect underrepresented populations at engineering institutions (Riley et al., 2014). Diversity is rarely mentioned in engineering classrooms, which continues to marginalize underrepresented students (Foor et al., 2007; Riley et al., 2014). One clear example of this non-inclusive environment in engineering was the presence of female faculty who brought different sets “ways of thinking, doing, and being” that were outside the established norms (Godfrey & Parker, 2010, p. 15). Acceptance of female faculty was achieved only through assimilation and their ability to adapt to the already established culture.

In the case of students, acceptance was achieved only if students also adhered to the assumed engineering norms. According to Godfrey and Parker (2010), undergraduate students in engineering programs could develop friendships only if they shared the same interests and educational or ethnic backgrounds. Ethnicity played an important role in acceptance. Although some female students could feel marginalized, they were accepted by their male counterparts if they shared the same ethnicity (Godfrey & Parker, 2010). Thus, participation of ethnically diverse students in engineering is affected by the difficulty to gain acceptance among their peers. In addition, this leads to the strong “us” and “them” views of underrepresented students reported by Stevens et al. (2008) and Foor et al. (2007).

Relationships

Godfrey and Parker (2010) described “relationships” as a cultural dimension where a set of beliefs and assumptions dictate how individuals relate to one another. Undergraduate engineering students needed strong relationships in order to succeed (cf. Martin, Simmons, & Yu, 2013). Stevens et al. (2008) argued that one engineering cultural norm was to form groups where students socialized and studied together for long periods of time. In fact, success was considered difficult for those marginalized students who did not engage in these practices because others would not accept them into their groups (Godfrey & Parker, 2010). Unfortunately, the lack of strong relationships in engineering becomes disadvantageous for those students with different ethnic or educational backgrounds. Those individuals who were seen as “different” became “at risk” students in engineering environments (Godfrey & Parker, 2010, p. 17). In addition, the norm of creating and participating in homogeneous groups can actively serve to marginalize underrepresented students (Tonso, 2006). Foor et al. (2007) talked about the feeling of alienation created when students did not feel they were part of the group. Some students become insiders while other become outsiders from the exacerbation of the “us” and “them” dynamics (Foor et al., 2007; Stevens et al., 2008). Eventually, those students that do not build “relationships” are less likely to be identified as engineers and leave (Stevens et al., 2008).

Relationship to the Environment

The cultural dimension of “relationship to the environment” described the set of assumptions and beliefs related to the perceived relationship of engineering education with the institution and the engineering profession (Godfrey & Parker, 2010). Godfrey and Parker (2010) argued that the faculty and students in their study perceived themselves as a completely separate entity from the rest of the university. Part of it was attributed to the physical location of the college, which was separated from the rest of the university campus. In addition, those beliefs and assumptions were also rooted in their “pride and sense of superiority in its ability to solve problems” (Godfrey, 2014, p. 445). Although the students and faculty perceived engineering as self-sufficient, most of the decisions taken by the college were based on university regulations and industry.

This view of engineering as a self-sufficient, separate entity may cause many students to become disillusioned with engineering because they cannot see how it relates to actual engineering experience, to their communities, or broader social and political trends (Godfrey & Parker, 2010). In addition, Godfrey (2014) argued that institutional structures are shaped not only by the culture of engineering but also by economic and political factors. Overall, engineering is affected by its relationship to the environment around it, including cultural shifts. In order to create a more diverse and inclusive environment, engineering education may need to more fully acknowledge these external factors (Stevens, Johri, & O'Connor, 2014).

Engineering Education and Marginalized Groups

The cultural dimensions of engineering described how engineering norms can turn some students away from the engineering path, especially underrepresented students. Students from different backgrounds may find it difficult to identify as engineers when their ways of knowing and doing are in conflict with those of the dominant culture (Foor et al., 2007; Godfrey & Parker, 2010; Riley et al., 2014; Stevens et al., 2008). In addition, the conflicting view of what is knowledge and what kind of knowledge is valued is very important in order to understand how Discourses play an important role in engineering education. Moreover, it is important to understand how the "engineering way of thinking" may affect Latino underrepresentation. Interestingly, Godfrey and Parker (2010) indicated that

> there was an unquestioned assumption by faculty that the knowledge, the mathematical procedures and scientific processes, and the laws on which problem solutions were based were race and gender free. No recognition appeared to exist that the ethnocentricity and masculinity of engineering knowledge and procedures might affect problem definition and accepted methods of problem solution, teaching, and assessment. (p. 12)

The fact that engineering is a male-dominated, ethnocentric field was not acknowledged by faculty, and culturally appropriate solutions developed by underrepresented students were seen as irrelevant answers rather than as alternative methods for problem solution. The "engineering way of thinking" did not account for the underrepresented students' ways of knowing, and it did not account for the existence of alternative epistemologies (Godfrey & Parker, 2010). Godfrey and Parker concurred with Bucciarelli, Einstein, Terenzini, and Walser (2000) in that students may possess valid ways of knowing that contribute to the engineering field, yet they differ from the legitimized engineering norms.

Moreover, the "engineering way of knowing" and the "engineering way of doing" are part of the shared beliefs and assumptions among people who practice "being an engineer" (Godfrey & Parker, 2010). These six cultural dimensions provide an insight to the engineering cultures and the difficulties that underrepresented students face when navigating engineering (Stevens et al., 2008). The quality of engineering could be negatively affected by these engineering cultures, which lead to a lack of diversity (Pawley, 2009; Riley et al., 2014). The absence of different life experiences could affect engineering solutions since creativity and other factors pertaining to engineering thinking and designing depend on life experiences (Wulf, 1998). Unfortunately, this absence of diversity is not something that the cultures of engineering often see or acknowledge due to the long-accepted practices in engineering (Godfrey, 2014).

An integral part of the "ways of knowing" is the practices, beliefs, and values that are part of our everyday lives. Hammer and Elby (2003) described these ways of knowing as epistemologies developed by the students in their everyday lives and used under different contexts and domains. The six cultural dimensions of engineering education described by Godfrey and Parker (2010) highlighted the absence of epistemologies that involved students' social and cultural practices, which may contradict the "engineering way of thinking" or could be perceived as not sophisticated epistemologies. Thus, the lack of integration of cultural and social practices in engineering education may create an intimidating environment for underrepresented students.

Foor et al. (2007) described in their qualitative study how the cultures of engineering generate a feeling of alienation and marginalization to minority students. Engineering culture was described by the authors in terms of the cultural knowledge and behaviors that prevail in engineering by the dominant class (i.e., White, male, middle class) (Bourdieu, 1977). The dominant class tends to have the same dispositions and interests; thus they adopt the same stance creating a subdivision that excludes other classes or microcultures such as underrepresented minorities (Foor et al., 2007). Also, the study indicated that the dominant culture in engineering has tried to perpetuate the belief that success in engineering is related to meritocracy (Foor et al., 2007; Godfrey, 2014; Godfrey & Parker, 2010; Stevens et al., 2007), that failure is the students' own fault (Foor et al., 2007; Godfrey & Parker, 2010), or that changes in curriculum are not necessary to accommodate different ways of learning and knowing (Foor et al., 2007; Riley et al., 2014). However, these beliefs do not take into account the sociological and cultural context of the engineering culture, or the cultural, social, and symbolic capital of the students (Foor et al., 2007).

Moreover, the culture of engineering may affect how minority students see and perceive themselves in engineering. Some students from the non-dominant culture do not know how to play the "game of academia" and can easily recognize the distinctions made within the engineering culture based on achievement and opportunity (Foor et al., 2007). This perception also leads students to have the notion that they live in separate worlds (e.g., an engineering world and their everyday world) where dissimilarities persist. The support or exclusion experienced in the engineering culture becomes a determining factor in the retention, recruitment, and success of underrepresented minorities in engineering (Seymour & Hewitt, 1997; Stevens et al., 2005, 2008).

Underrepresented Students' Cultures and Engineering

The exclusion of underrepresented minorities in engineering has been explained through multiple factors. One of those factors includes the lack of a development of an identity with engineering or being an engineer (Stevens et al., 2005). According to Stevens et al. (2005), identity in engineering education is a key factor in retaining students in engineering, particularly underrepresented students. It is important for the students to see themselves as being part of the engineering community and build a sense of belonging in order to stay in engineering. It is through identity that individuals understand the ways in which they are positioned, but also how they are situated socially (Foor et al., 2007; Stevens et al., 2005, 2008).

However, students may struggle to create an engineering identity that contradicts their social and cultural worldviews of underrepresented students. Aschbacher, Li, and Roth (2010) argued that it is through social interactions that students develop and construct their identities, as well as “who they are or wish to be in relation to these communities” (p. 566). The process of socialization and the experiences in engineering helps students develop their sense of belonging and the desire to continue in engineering (Tonso, 1996). Unfortunately, for many underrepresented students the social interactions and experiences in engineering may not lead to the development of an engineering identity, forcing underrepresented students to leave.

Stevens et al. (2005) described the case studies of two female engineering students alienated by engineering culture. One of the students was Mexican American while the other was Native American. Both students engaged in different project-based courses during their freshman year in college, similar to an internship. Interestingly, both women agreed that engineering education did not provide them with supportive personal development (Stevens et al., 2005). The Native American student indicated that the “real world” experiences during the internship helped her with her school work rather than seeing the internship as an opportunity to gain life abilities or expertise (Stevens et al., 2005). On the other hand, the Mexican American student indicated that she was a “very people person” and that it was difficult for her to see where engineering would “fit into that” (Stevens et al., 2005, p. 6). She considered being a “people person” a gift but during her internship she was not exposed to helping other people, which became a significant factor that made her reconsider engineering and leave.

Although both students participated in project-based engineering activities, the socializations and the experiences did not help them build an engineering sense of belonging or identity. The bottom line for these two female students was that engineering was not a place for personal development (Stevens et al., 2005). For example, the values and cultures of the Mexican American student (i.e., helping other people) did not fit in with the competitive environment of engineering (Foor et al., 2007; Godfrey & Parker, 2010; Tonso, 2006), or the idea that engineering is only applied math and science, making things, and solving problems (Pawley, 2009). She was determined to leave the engineering program after the internship because the internship experience did not meet her expectations and being a "people person" clashed with engineering. The interaction and socialization with other members of the engineering community, as well as her own experiences during the internship, influenced how she saw herself in engineering and as part of that community.

Interactions with teachers, family, and other individuals can influence how we identify ourselves and develop our interests. Aschbacher et al. (2010) analyzed the science identity of 33 high school students and their trajectories into science, engineering, and medical (SEM) related fields. This study followed students from diverse backgrounds who were interested in SEM-related careers. For example, one Latina high school student indicated that she was interested in becoming an engineer because she enjoyed fixing appliances at home. Aschbacher et al. (2010) argued that high school students who were initially interested in SEM-related careers did not follow through because of different factors including school experiences that failed to encourage or support their interests. Students began to perceive SEM careers as very "hard" and assumed that becoming a scientist or engineer would become impractical.

In addition, the lack of compelling extracurricular activities was one of the factors that pushed underrepresented high school students away from the SEM pipeline (Aschbacher et al., 2010). The students involved in extracurricular activities, such as robotics clubs or summer research programs, expressed their disappointment with the type of experiences they were involved in. Students lost interest and eventually left the SEM pipeline because the project rationale was almost never explained and there was "little opportunity to discuss and see the relevancy of their work" (Aschbacher et al., 2010, p. 573). This example correlates with similar observations made by Stevens et al. (2005) indicating that underrepresented students lost interest in engineering due to the lack of relevancy and connectedness to their values and cultures. Adams et al. (2011) emphasized the importance of creating connections between the new and the old, and the abstract and the concrete, in order to create engaging engineering experiences for students. Similarly, it is important for Latino students to see how engineering relates to their everyday lives. Values such as "caring" or being a "people person" (Stevens et al., 2005), which are not reflected in engineering cultures, may be important to many minority students. Integrating information from a wide range of sources, including affective factors, cultivates the sense of relevance of engineering work of underrepresented students (Adams et al., 2011).

Cultural Border Crossings

Students may encounter different conflicts when their everyday life world does not connect to the science classroom world. As mentioned previously, culture and social interactions influence the cognitive processes of students and their sense of belonging and identity (Aschbacher et al., 2010). Jegede and Aikenhead (1999) argued that learning is "a social process mediated by culture and is significant in accomplishing the construction of meaning in new situations" (p. 45). Culture plays an important role not only in achievement but also in other cognitive activities, including learning science (Adams et al., 2011; Lee, 2001).

Students encounter a clash of microcultures when they view the world of science and the world of their everyday lives differently. Lee (1999) explained that students bring with them their own way to see and interpret the world. These world views are representative of their social and cultural environments and personal experiences. In Lee's study, children were asked to describe a major natural disaster – a hurricane – in terms of the nature, formation, and impact of the hurricane. The fourth and fifth grade students drew from different sources of information including family relationships, television, radio, and other social organizations. Interestingly, African American and Hispanic students had limited scientific knowledge of the hurricane but their knowledge of hurricane prediction, hurricane preparedness, and damage caused by the hurricane was "accurate and elaborate," mostly because of their personal experiences with the hurricane (Lee, 1999, p. 189). In addition, African American and Hispanic students "expressed world views in which people or society, nature, and supernatural forces all played important roles in an integrated manner" (Lee, 1999, p. 204). The world views of African American and Hispanic students, obtained from different sources, were often incompatible with the views of Western science (Lee, 1999). On the other hand, their Caucasian counterparts expressed world views that were usually more compatible with views of Western science.

Although the underrepresented students demonstrated an adequate knowledge about the consequences of hurricane from personal experiences, the students failed to develop a coherent understanding of the nature and science behind hurricanes (Lee, 1999). Nonetheless, students created meaning of the hurricane based on multiple sources of information. According to Lee (1999), underrepresented students' science knowledge was related to information sources and world views in social and cultural contexts. The incompatibility between Western science and the students' information sources led the students to create alternative views regarding the nature of hurricanes. The task of reconciling different and incompatible ideas create a greater challenge for underrepresented students who try to make sense of dissimilar world views, such as the worldviews they are presented with at home and the worldviews they are presented with in STEM classrooms (Lee, 1999, 2001). This discrepancy becomes a challenge not only for students but also for teachers who may fail to recognize the knowledge and experiences that underrepresented students bring to the classroom (Lee, 2001).

Aikenhead and Jegede (1999) offered a cognitive explanation to the problem faced by students regarding dissimilar world views in science. Students face "cultural border crossings" when making transitions between microcultures divided by borders (p. 272). The authors described K-12 students' conflicts when they move between two different worlds, the world of science and their everyday life world, as a cultural border crossing. A cultural border crossing represents the "multiple identities of individuals as a result of living in in a world of border crossings and the multiple narratives that define their reality" (Giroux, 1992, p. 54). Cultural border crossings are created when students cross their familiar everyday life world into the unfamiliar world of science.

Students' everyday life experiences encompass the human phenomena related to learned behavior patterns distinctive of a culture, such as the "norms, values, beliefs, expectations, and conventional actions" of a group creating a microculture (Aikenhead &

Jegede, 1999, p. 272). On the other hand, science can be described as another type of microculture since the science community shares unique combinations of the same values, norms, beliefs, expectations, and conventional actions within that group. When the students move between these two microcultures, they experience a cultural clash where “not only the concepts are different but the epistemology also differs” (Aikenhead & Jegede, 1999, p. 276). The cultural clashes created from this cultural border crossing can make learning very vulnerable for the students. Students may avoid constructing scientific knowledge or align only with scientific knowledge that does not interfere with their everyday life experiences (Aikenhead & Jegede, 1999). The conflicts arising from the microcultural clash do not help students since they must learn how to deal with cognitive conflicts, especially when the transition between the science world and the everyday life world is not addressed by their teacher. Therefore, the ideology of “science for all” is not attainable unless a culturally sensitive curriculum embraces the students’ everyday life experiences and the social context of learning science and engineering (Lee, 1999). For instance, teachers could at least acknowledge and seek to understand students’ worldviews, and allow them to voice them in class while also teaching students the principles that are accepted by the scientific community.

Culturally Responsive Education

Ladson-Billings (1995) proposed the theoretical underpinnings of a culturally relevant pedagogy. According to Ladson-Billings, three criteria must be met: “ability to develop students academically, willingness to nurture and support cultural competence, and development of a sociopolitical or critical consciousness” (p. 483). She emphasized the importance of “allowing students to maintain their cultural integrity while succeeding academically” (Ladson-Billings, 1995, p. 476). Therefore, the goal of instruction is not to infuse the classroom with a complete change in curricula but to learn more about the students and challenge deficit thinking.

According to Valencia (1997), deficit thinking describes the belief that students fail or do not succeed because of internal deficits or deficiencies. Although the deficit thinking model lacks empirical validations, it has a powerful influence in educational practice (Valencia, 1997; Valencia & Black, 2002; Valenzuela, 1999). One of the main characteristics of deficit thinking is the idea that skills and attitudes of the students are to blame for their failure, rather than the lack of structural changes in the schools. The notion that underrepresented students possess motivational and cognitive deficits marginalizes students and promotes the model of meritocracy in educational structures (Valencia, 1997; Valencia & Black, 2002). Similarly, the meritocracy myth in engineering is what keeps underrepresented students away from engineering-related careers (Foor et al., 2007; Stevens et al., 2007, 2008). By learning from their students’ knowledge resources, ways of knowing, and world views, teachers have an opportunity to promote learning in ways that are meaningful and relevant while challenging the deficit thinking model (Lee, 2001). It is the intent of culturally sensitive, relevant, and responsive education to maintain heritage ways while providing a space where education becomes relevant to the students (Paris, 2012).

Gay (2010) argued that culturally responsive education practices should incorporate multiethnic cultural frames of reference. In order to achieve this goal, instructors must look into the cultures of the students and cultural diversity of the classroom. Culture is multidimensional, changes continuously, and it is influenced by different factors such as socioeconomic, educational, or geographical circumstances. Recognizing the ways of knowing and doing of students based on their cultural and social experiences acknowledges the cultural heritage of the students, and learning is approached by students as something meaningful and tangible (Gay, 2010; Lee, 2001). The cultures of school may not always synchronize with student cultures, in part because the way that "culturally diverse individuals engage in intellectual processing, self-presentation, and task performance is different from the processes used in schools" (Gay, 2010, p. 12). However, creating bridges between the meaningfulness of school and home experiences is both validating and affirming for the students (Gay, 2010). Thus, it is important to get to know meaningful for students.

To achieve this goal, Irizarry (2007) observed how an African American history teacher at an urban high school practiced culturally responsive teaching in a culturally and linguistically diverse classroom. The teacher used different methods to connect the worldviews of the students with abstract concepts in the classroom. First, the teacher included personal stories about his own challenges as an African American to connect with the students. These conversations allowed the students to bring their cultures to the classroom and create a culturally connected identity with the teacher. In addition, the teacher supported the use of students' language preferences in the classroom. The students felt comfortable and engaged more in the classroom because different cultural variations of literacy were encouraged (cf. Warren, Bellenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001). The practices carried by the teacher in this study also allowed the students to reinforce their group identity. Thus, it could be significant and valuable in engineering education to adopt culturally responsive teaching methods in order to help underrepresented students develop their sense of belonging in engineering and engineering identity (Foor et al., 2007; Stevens et al., 2007, 2008).

Education in the culturally and linguistically diverse classroom must separate from the "deficit thinking" belief and approach education in a more inclusive way. Attention must be given to maintaining, celebrating, and considering the students' cultural and linguistic resources as assets rather than deficits. Teaching must be "relevant and responsive to the languages, literacies, and cultural practices of students" (Paris, 2012, p. 93). Historically, only the dominant language and culture were accepted and viewed as superior practices, thus leading to the eradication of other cultural ways of being (Paris, 2012; Paris & Ball, 2009; Valdés, 1996). To counter this historical trend, culturally responsive education should not only involve an understanding of the different cultural practices of students, but it should foster and sustain the pedagogies that embrace this pluralism.

Funds of Knowledge

Several scholars (Barton & Tan, 2009; Gonzalez et al., 2005; Moje et al., 2004; Moll et al., 1992) have asserted that one way to provide culturally responsive education is by drawing from students' funds of knowledge. The combination of classroom and everyday life knowledge can be combined in formal classroom learning to provide culturally responsive instruction (Paris, 2012). The work of Moll et al. (1992) provided evidence that students can successfully bring their funds of knowledge to the classroom and use them as powerful learning tools. The framework used in the funds of knowledge project by Moll and colleagues provided a venue for students to bring their cultural and linguistic practices to the classroom (Moll & Arnot-Hopffer, 2005). Moreover, the work on funds of knowledge opened new research venues where home and community practices were joined with educational paradigms in meaningful ways to increase learning and access for those who have been historically marginalized.

The term funds of knowledge is often associated with the work of Moll et al. (1992) and their work with children, teachers, and parents from U.S.-Mexico borderlands in the Southwest. However, the term was originally coined in Velez-Ibañez and Greenberg's (1990) anthropological work. According to these scholars, funds of knowledge can be described as the strategic and cultural resources and skills that the students have accumulated historically and culturally (cf. Gonzalez et al., 2005; Moll et al., 1992; Oughton, 2010; Velez-Ibañez & Greenberg, 1992). Velez-Ibañez and Greenberg (1992) argued that the cultural and behavioral practices of people in the U.S.-Mexican borderlands were characterized by "specific strategic bodies of essential information that households need to maintain their well-being" (p. 314), known as funds of knowledge. For example, some of the funds of knowledge described by these authors included those bodies of knowledge related to building, carpentry, folk medicine, mining, water management, and household maintenance among other types of knowledge required for people's survival. Families' funds of knowledge included not only the complex knowledge and skills necessary to maintain their well-being, but also the values, beliefs, and ideologies gained through social and cultural practices. These funds of knowledge were transferred to the children through "the question-answer process" where the children had an active role in the learning process (Velez-Ibañez & Greenberg, 1992,

p. 326). The study showed that Latino families in the U.S.-Mexico borderlands forged their identities through this learning process, and they acquired funds of knowledge through cultural and social practices.

Similarly, Moll et al. (1992) drew from the definition of funds of knowledge of Velez-Ibañez and Greenberg (1992) in order to understand the intersectionality between social networks and the exchange of resources, bodies of knowledge, and skills. The study identified several categories of household funds of knowledge that included bodies of knowledge, skills and practices related to agriculture and mining, economics, household management, material and scientific knowledge, repairs, medicine, folk medicine, and religion (Moll et al., 1992). For example, some of the bodies of knowledge and skills that emerged from those household funds of knowledge included knowing how to harvest and plant crops, how to operate machinery, how to do appraising and sales, create budgets, cook, and herbal knowledge among others.

It is important to mention that the initial intention of the funds of knowledge research was to address the perceived “deficits” of low-income, culturally and linguistically diverse students (Rodriguez, 2013). Initially, the research tried to challenge the deficit thinking model by providing a spectrum of bodies of knowledge, skills, and practices that underrepresented students possessed, which could be used in classrooms to create more inclusive environments (Rodriguez, 2013). However, the concepts of funds of knowledge have changed to include other types of funds of knowledge that are relevant to new and evolving sources of knowledge that can include mass media or digital technologies (Marsh, 2011; Marsh, Brooks, Hughes, Ritchie, & Roberts, 2005; Moje et al., 2004).

Funds of knowledge emerge from different historical, social, and cultural contexts, and each household shows specific characteristics. According to Velez-Ibañez and Greenberg (1992), “each household has a characteristic emphasis, a type of cultural shape that differentiates one household from another and that is derived from historical circumstances” (p. 318). Also, funds of knowledge are expressed in different contexts and used in a variety of settings having an impact on everyday life. However, although the funds of knowledge are generational, if the individuals are not able to “transliterate” the knowledge in new, meaningful ways, the individuals would not be able to gain functional understanding of the funds of knowledge obtained from their ancestors (Velez-Ibañez & Greenberg, 1992).Velez-Ibañez and Greenberg’s work emphasized the importance of investigating and embracing the funds of knowledge that households contain in order to highlight their significance and use them as assets in the classroom. The following sections describe the way that the funds of knowledge framework has been used in different educational contexts.

Funds of Knowledge and Education

Ethnographic studies have been done regarding the use of funds of knowledge in an educational and praxis-oriented context (Civil, 2006; Gonzalez et al., 2005; Gonzalez & Moll, 1995; Hedges, Cullen, & Jordan, 2011; Moll et al., 1992). Moll et al. (1992) performed a series of ethnographic and anthropologic studies to collect data that included household information regarding a group of students in the Southwestern U.S. Their work documented different funds of knowledge based on life experience, thick social networks, and survival strategies the students gained from their homes. The students obtained thick funds of knowledge not only through generational channels, but also through different "systems of exchange" characterized by the relationships the students built with family and community members (Moll et al., 1992, p. 139). The purpose of this study was use an inquiry process with teachers to learn more about the learning processes occurring at home and connect it to learning processes at school (Rodriguez, 2013). By informing teachers about the learning that occurred at home, the teachers expected they would be better prepared to connect the students' everyday lives knowledge to classroom knowledge.

Moll et al. (1992) emphasized how understanding the funds of knowledge was crucial for the transformation of negative beliefs and attitudes toward underrepresented minority students (Gonzalez et al., 2005; Oughton, 2010). The benefits of understanding students' funds of knowledge included better relationships between parents, teachers, and students. Teachers who understood these funds of knowledge were also able to create curricula that reflected students' and families' knowledge to create a more empowering pedagogy (Moll et al., 1992). Teachers who solicited students' funds of knowledge understood how they learned and how to provide the attention the students needed to build on previous knowledge.

The theoretical and methodological approach used to investigate the funds of knowledge of Latino families in the Southwest challenged the deficit interpretations of how marginalized students learn, relate to others, or participate in learning practices. Because school systems often overlook the cultural resources emerging from households, "understanding the funds of knowledge is necessary in order to improve the quality and equity in schools" (Velez-Ibañez & Greenberg, 1992, p. 313). There is a tendency to correlate cultural and racial differences with deficit (Harry & Klinger, 2007).

Nonetheless, students of color possess valuable funds of knowledge that enable them to cope and adapt to changing circumstances and contexts.

Funds of Knowledge in Science and Mathematics Education

Other studies (Barton & Tan, 2009; Barton, Tan, & Rivet, 2008; Civil, 2002; Moje et al., 2004; Moje, Collazo, Carrillo, & Marx, 2001; Moll et al., 1992) have investigated the funds of knowledge in Latino communities in U.S. schools and how teachers can use these funds of knowledge to create engaging and socially relevant curricula in science and mathematics. Moje et al. (2004) analyzed how Latino students' funds of knowledge shaped their ways of knowing and doing, also known as Discourses. Gee (2008) described Discourses as the ways of knowing, doing, talking, valuing, reading, and writing that are part of the social aspects of everyday life. The purpose of Moje and others' study was to analyze the students' experiences in order to "construct classroom spaces that can integrate in- and out-of-school literacy practices" (p. 41). The authors found that the integration of multiple funds of knowledge and Discourses is an important part of science education in order to help students "navigate" through different Discourses, including the "science community Discourse" (p. 44). Moreover, the importance of works involving funds of knowledge and science education allow for conversations to arise from different social and cultural practices and Discourses to challenge the dominant Discourse (A. Barton, 2001; Barton & Tan, 2009; Gonzalez & Moll, 1995; Moje et al., 2001, 2004).

Moje et al. (2004) focused on the different funds of knowledge available to Latino students, which included bodies of knowledge, skills, and practices obtained through family, the community, peer groups, and popular culture. Similar to the work of Moll et al. (1992), Moje and colleagues identified family funds of knowledge as those bodies of knowledge that revolved around the work of parents in and out of home. Community funds of knowledge involved knowledge and Discourses evolving from students' shared identities and a "sense of collective struggle" with community groups or organizations (Moje et al., 2004, p. 56). Peer funds of knowledge included formal and informal peer activities, while the popular culture funds of knowledge emerged from the bodies of knowledge and Discourses related to the students' familiarity with popular media such as magazines, music, or television.

The results of the study indicated that students made connections between their funds of knowledge and science learning. For example, students drew from their knowledge of cooking procedures at home to understand science concepts such as condensation and evaporation. Moje et al. (2004) argued that teachers could develop an understanding of the funds of knowledge and Discourses of their students in order to provide the students with relevant science learning in the classroom. They also argued that teachers must be willing to create a space where different forms of knowledge and Discourses are welcomed. Through these practices, teachers provide a safe space for students where they can share their funds of knowledge.

In a similar study, Barton and Tan (2009) adapted and expanded the work of Moje et al. (2004) in order to identify the funds of knowledge and Discourses used by students in the science classroom. Their study involved a group of low-income, urban, middle school students working on different activities in the science curriculum. As opposed to concentrating on their workplace experiences, Barton and Tan (2009) expanded the family funds of knowledge to include family life involving nutritional habits, family and ethnic traditions, material capital, and food preparation.

For example, for a lesson on the different parts of a plant, students were asked to gather information from their families and share their favorite home salads. This activity allowed students to actively participate in class, share something they were familiar with, and contribute to the classroom science discourse. Home interactions, such as learning from parents about healthy foods, created a sense of nutritional awareness developed through home funds of knowledge and learning from those experiences. Discussing the home salad recipes with family members provided students with the rationale to engage in scientific discourse in the classroom regarding the good nutritional value of salads (Barton & Tan, 2009).

In addition, students in this study drew from community funds of knowledge, popular culture, and peer community funds of knowledge to “aid their participation in school science” (Barton & Tan, p. 59). Some of the funds of knowledge students drew from included music, fashion, fast food, solidarity, talents and interests, internet and television among others. For example, after a nutrition-related lesson, students drew from their knowledge of television cooking shows to generate ideas about healthy and unhealthy meals. Barton and Tan argued that this instructional approach “fostered new opportunities to engage the subject matter that promoted both academic achievement and inclusion” (p. 66). When teachers actively incorporated students’ funds of knowledge, they engaged in class, shared their opinions, asked questions, and created connections with familiar concepts, thus making the science discourse more meaningful to them. It is through these types of teacher and student interactions that culturally responsive education becomes possible in the science classroom.

Barton and Tan's study not only identified students' funds of knowledge, but it also showed how they could be used to transform the learning of science for students. The study indicated that the funds of knowledge framework allowed the students to collectively create "hybrid spaces" where the "official school science discourse was challenged and its boundaries pushed to become more inclusive of students' everyday Discourses and knowledge" (Barton & Tan, 2009, p. 51). Based on the concept of Discourses presented by Gee (2008), Barton and Tan argued that adolescent Discourses are part of the students' identities and play an important role in the science classroom. Students' experiences shape who they are, and it is important to examine their funds of knowledge and Discourses in order to allow for a smooth transition from their everyday life world to the science classroom (Aikenhead & Jegede, 1999).

In the area of mathematics, Civil (2002) performed a study intended to connect students' everyday life experiences to mathematics education. Her study addressed the connections between "everyday mathematics" and "academic mathematics" (Civil, 2002, p. 133). Working with teachers and parents, Civil created modules for second grade students that connected community knowledge to mathematics content. The students had different opportunities to interact with members of the community and their families to learn about mathematics. For example, the students talked to a draftsman from the community about building blueprints. Then, using the information obtained from the draftsman, the students created their own blueprints and used shoe boxes to build their own haunted houses for Halloween. The activities within the module gave the students an introduction to different concepts such as scaling and generating three-dimensional models from two-dimensional drawings.

Another aspect of Civil's (2002) study included using parents' intellectual resources as sources of knowledge to create the mathematics modules. Occupational interviews were used to gather information about the parents and how they used mathematics at work or in the community. The interviews showed the "mathematical richness" embedded in the practices of the adults (Civil, 2002, p. 144). One of the examples provided by Civil (2002) was how adults, and their children, learn about geometric concepts through traditional Mexican craft activities, called "papel picado" (p. 145). The modules integrated these practices and experiences to create engaging and relevant activities for the students. The students relied on everyday knowledge and experiences, such as family funds of knowledge, to elaborate solutions and make sense of the mathematics concepts presented in the classroom.

The goal of the study was to develop mathematics instruction that was sensitive to the cultural backgrounds of students in a second grade classroom (Civil, 2002). The group of students was predominantly Mexican American (60%) with a small number of White (10%) and Yoeme (30%) students. Using observation, discussions, and interviews, Civil was able to analyze students' funds of knowledge that influence their "everyday mathematics" (p. 146). Similar to the works of Barton and Tan (2009) and Moje et al. (2004), the study emphasized the idea of bringing the funds of knowledge and experiences to the table and discussing them with a critical eye in order to create a transformative educational experience for the underrepresented students.

Engineering Design

Although much work has been done in science and mathematics to make the content engaging and inviting to underrepresented students, studies have indicated that underrepresented students do not find engineering learning contexts appealing (Lent et al., 2005; Seymour & Hewitt, 1997). Many women and underrepresented minorities do not identify with engineering activities or practices (Brophy, Klein, Portsmore, & Rogers, 2008; Foor et al., 2007; Stevens et al., 2005, 2008). Underrepresented students get discouraged from pursuing careers in engineering, resulting in declining numbers of diverse engineers in the workforce. To reverse this trend, K-12 educators must improve the preparedness of their students so they can successfully transition to higher education (Brophy et al., 2008; Carr, Bennett, & Strobel, 2012). Therefore, it is important to develop activities that could help underrepresented students, especially Latinos, engage and identify themselves as engineers.

Studies in engineering education have described different alternatives to engage students in engineering that include outreach programs (Adams, Turns, & Atman, 2003), service learning (Bielefeldt, Paterson, & Swan, 2010; Oakes et al., 2002), community engagement (Swan, Paterson, & Bielefeldt, 2014), project-based learning (De Graaff & Kolmos, 2003; Kolmos & De Graaff, 2014), and engineering design activities among others (Atman et al., 2007; Dym et al., 2005; Jonassen, 2014; Jonassen, Strobel, & Lee, 2006). Although several engaging engineering teaching and learning methods have been studied, this study takes *engineering design* as the avenue that can be used to engage Latino high school students, provide transformative experiences for the students, and allow the students to participate in engineering Discourses. Jonassen (2014) argued that engineering design "requires learners to make judgments and express personal opinions or beliefs about the problem" (p. 105). Thus, the essence of engineering design allows the students to bring their bodies of knowledge, skills, practices, and beliefs to provide solutions to problems.

Dym et al. (2005) described engineering design as "a systematic, intelligent process in which designers generate, evaluate, and specify concepts, devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints" (p. 103). This definition highlights the dynamic nature of engineering design where a constrained set of operations is not established. In general terms, engineering design problems can be described as ill-structured problems because they require the integration of several domains (i.e., problem scoping, idea generation, evaluation, and solution quality), are interdisciplinary in nature, and the constraints may or not be engineering-related (Atman et al., 2007; Jonassen, 2014; Jonassen et al., 2006; Simon, 1973). In contrast, well defined problems require the limited application of rules and principles, have specific solutions, and can be predictable (Jonassen, 2014). Through ill-structured problems and engineering design, students can learn to solve problems that are more meaningful and related to their everyday lives.

Atman et al. (2007) investigated how engineers and novices solved an ill-structured problem as they engaged in the engineering design process. The engineers were asked to design a playground – a type of problem they were unfamiliar with. During the study, the engineers were also asked to think aloud while they were recorded. Data analysis revealed that engineers engaged in three different design stages: (a) problem scoping, (b) developing alternative solutions, and (c) project realization. *Problem scoping* referred to the identification of criteria, constraints, and requirements to solve the problem. *Developing alternative solutions* involved thinking of potential or alternative solutions through experimentation or generation of ideas, while *project realization* referred to the process of deciding the possible solution to the problem and communicating that solution through various methods (Atman et al., 2007).

In addition, Atman and colleagues identified different sub-activities within the design stages. Problem scoping contained identification of a need, problem definition, and gathering information. Developing alternative solutions included generating ideas, modeling, feasibility analysis, and evaluation. Finally, project realization involved decision making, communication, and implementation. These results outlined how engineers move through the engineering design process through several stages while performing different activities until a final solution is reached. Atman et al. (2007) argued that these results could be used to improve engineering student learning and encourage educators to facilitate engineering design practices through these different lenses.

Engineering design activities involve ill-structured problems, which are encountered in everyday life and work and "are not constrained by the content domains being studied in classrooms" (Jonassen, 2014, p. 105). According to this definition, engineering provides a space where students are not limited by the assumed technical, methodological, and logical nature of engineering (Riley et al., 2014), or the perception that engineering is only the heavy application of mathematics and science (Foor et al., 2007; Godfrey & Parker, 2010; Pawley, 2009). Students have an opportunity to bring their own bodies of knowledge to engage in the engineering Discourse.

Engineering Design at the K-12 Level

Engineering design has been described as a STEM integrator that enhances the study of science and mathematics (National Research Council, 2009). According to the National Academy of Engineering and National Research Council (2009), the implementation and integration of engineering design in STEM at the K-12 level helps to generate interest in engineering among students. There are two main goals for improving engineering education at the K-12 level: raise the level of scientific and technological literacy and prepare students to pursue careers in STEM (National Academy of Engineering and National Research Council, 2009). Nonetheless, the delivery and instruction of engineering varies from school district to school district.

At the high school level, there are no explicit standards or guidelines that indicate what the appropriate level and area content should be included in engineering design activities (Carr et al., 2012; Householder & Hailey, 2012). The complexity of engineering design challenges, such as having different possible solutions or constraints, make it difficult to create detailed lesson plans, lab exercises, or specific instructional strategies (Householder & Hailey, 2012). Therefore, there is a need for more guidance on the implementation and direction of engineering design challenges at the K-12 level. It has been argued that, although it is difficult to implement engineering design challenges in K-12 contexts, this approach leads to the improvement of problem solving abilities and increases interest in engineering (Brophy et al., 2008; Dym et al., 2005; Householder & Hailey, 2012; Jonassen, 2014; Jonassen et al., 2006).

Several engineering design models have been developed in an effort to describe the practice of engineering and apply it to the high school setting appropriately (Achieve

Inc., 2013; Guerra, Allen, Crawford, & Farmer, 2012; Hynes et al., 2011; Massachusetts Department of Education, 2006; Sheppard, Macatangay, Colby, & Sullivan, 2009). Despite differences in these models, they all share the goal of developing students' design abilities, which reflects the processes of inquiry and learning that designers perform in a systems context by making decisions, collaborating with others, and even speaking several languages with each other (Dym et al., 2005; Jonassen, 2014). In other words, design thinking allows students to explore solutions to ill-structured problems in a holistic way while considering different constraints.

Working under this assumption, Moore et al. (2014) proposed a framework for quality K-12 engineering education that integrates several dimensions of engineering beyond scientific and mathematical knowledge. Although the framework does not provide a specific engineering design model that can be used as a standard, the framework described several key indicators that are included in different engineering design models. According to Moore and colleagues, the framework allows for the development and implementation of engineering education practices that will ensure the engineering preparedness of K-12 students. The framework contained nine key indicators: (a) process and design; (b) apply science, engineering, and mathematics; (c) engineering thinking; (d) conceptions of engineers and engineering; (e) engineering tools; (f) issues, solutions and impacts; (g) ethics; (h) teamwork; and (i) communication related to engineering.

Moore and others' framework was designed to summarize what students in K-12 should understand and to delineate the content that engineering-related activities should contain. The process and design indicator specified that students in K-12 should "learn the core elements of engineering design processes” and apply them to realistic situations (2014, p. 5). Those core elements of engineering design included problem scoping, collecting background information, plan implementation, and testing and evaluating – similar to the design stages identified by Atman et al. (2007). The rest of the indicators described the different habits of mind, dispositions, and aspects of engineering that emphasize the interdisciplinary nature of engineering. For example, students should be empowered to believe that they can solve problems on their own by engaging in engineering thinking while understanding the impacts of their solutions in a “global, economic, environmental, and societal context” (Moore et al., 2014, p. 6). Moreover, the teamwork, communication, ethics, and tools indicators are not only essential for engineering education but are also required for success in multiple disciplines.

According to Householder and Hailey (2012), engineering design challenges can be described as “ill-structured problems that may be approached and resolved using strategies and approaches commonly considered to be engineering practices” (p. 2). These challenges may affect an aspect of everyday life, and finding a solution to such a problem involves the use of different processes similar to those used in the professional practice of engineering (Jonassen, 2014). Finding the solutions to these problems involves the integration of science, mathematics, and technology, but also everyday life knowledge and prior experiences (Jonassen, 2014). These “challenge-based” environments motivate students to solve problems, especially if they are embedded in familiar activities that increase the likelihood of the students to explore the variables (National Academy of Engineering and National Research Council, 2009). For this reason, community-based challenges provide a venue for the students to connect with their everyday life world, and allow the students to take personal ownership of the context of solving the problem (Jonassen, 2014; Riley et al., 2014).

The implementation of engineering design at the high school level is an appropriate venue where funds of knowledge of Latino students can be examined, especially when students work on community-based challenges. High school offers an opportunity for Latino students to learn about the engineering design process in a meaningful and holistic way. The interactions between students allows for the perfect setting where students can frame problems, test and evaluate their ideas and solutions, and analyze the constraints that would generate an optimal solution to an engineering design challenge (Householder & Hailey, 2012). It is important to explore the benefits of using community-based engineering design challenges at the K-12 level to develop culturally responsive engineering education models that help underrepresented students succeed.

Summary of Literature Review

The literature review focused on the cultural dimensions of engineering, culturally responsive education, cultural border crossings, funds of knowledge, and engineering design. The review highlighted the different cultural dimensions that may keep Latino students away from pursuing engineering degrees. These cultural dimensions comprised different factors that affect Latinos, such as the lack of identification with engineering and being an engineer, the different ways of knowing and doing of Latinos that may contradict the engineering way of thinking and doing, and the cultural borders that exist between the everyday lives of Latinos and the engineering Discourses. Unfortunately, as stated by Aschbacher et al. (2010), Latino students go through different experiences that discourage them to continue in the engineering pipeline. The lack of exposure to engineering design creates a misinformed perception of engineering where only right or wrong answers are possible (Foor et al., 2007; Godfrey & Parker, 2010). Also, the absence of compelling engineering activities for the students, as well as the failure to identify themselves as engineers, pushes Latino students away from engineering careers. However, creating bridges between students' everyday lives and engineering Discourses could cultivate a sense of belonging in engineering in the engineering community and promote the relevance of engineering education.

Engineering education must acknowledge the ways of doing, knowing, and thinking that emerge from social interactions of Latino students, which may differ from the structured engineering norms. Engineering education, especially at the K-12 level, needs to include a holistic approach to engineering design (Jonassen, 2014), which could lead to more participation and empowerment of Latinos in engineering. Adams et al. (2011) emphasized the need to build connections between prior knowledge and new knowledge in order to create compelling and engaging engineering experiences for the students. Although there have been studies related to the funds of knowledge of Latino students in science and mathematics education, the literature review suggests that studies documenting the funds of knowledge of Latino students in engineering has been limited. This study therefore moves toward culturally responsive engineering education by identifying Latino students' funds of knowledge that can be connected to engineering.

CHAPTER 3

PILOT STUDY

During the 2012-2013 school year, a pilot study was conducted to investigate the funds of knowledge of Latino adolescents as they worked on community-based engineering design problems. The pilot study was used to become acquainted with the funds of knowledge of Latino adolescents, refine the interview protocols, and collect data to build on the funds of knowledge framework. The methodological design for this pilot study is identical to that of the full study; therefore, a detailed description of the methods can be found in Chapter Four. The purpose of this chapter is to detail the work performed during the pilot study and provide specific examples of how the data were analyzed to create the funds of knowledge framework that was later used for the full study.

Overview of Pilot Study

Different educational research methods have been, and could be, used in engineering education including qualitative research methods that offer interpretive research quality (Borrego et al., 2009; Walther et al., 2013). The pilot study was based on an ethnographic approach to qualitative research (Case & Light, 2014; Tedlock, 2000) to investigate the funds of knowledge of Latino high school adolescents. Ethnographic research methods are appropriate for studying culture because they enable researchers to describe and interpret patterns of behavior, customs, and ways of life (Creswell, 2012). In particular, the purpose of the pilot study was to analyze the funds of knowledge of Latino high school adolescents and improve interview protocols and research strategies for the full study.

Ten adolescents were recruited from one high school in a rural area in the Western United States. The participants, four boys and six girls, were selected for this study on a volunteer basis. Two different venues were used to recruit the students: (a) the local Mathematics, Engineering, and Science Achievement (MESA) club, and (b) the Latinos in Action club. MESA was an after school program whose main purpose was to help underrepresented students achieve excellence in mathematics, science, and engineering through different activities, such as the prosthetic arm challenge. Latinos in Action was a school program where students learned how to be agents of change and leaders in their communities while participating in different service projects. All students that volunteered to participate in the pilot study spoke Spanish at home and most of them had recently received English as a second language (ESL) services at their school. The adolescents recruited for the pilot study attended the same high school and were involved in some of the same extracurricular activities. All participants came from working class families.

After the participants were selected for the pilot study, they were grouped in three different teams and each team worked on a specific community-based project selected by the team members. The participants were grouped according to their geographical location; in other words, participants who lived in the same neighborhoods were in the same groups. This method of grouping made it easier for them to get together and discuss their project every two weeks. Each team was asked to brainstorm different ideas about problems in their community that they would like to address. The first group, consisting of two girls and one boy, worked on improving and expanding a small playground in their neighborhood. The second group, consisting of four girls, improved an existing device for restraining cats while they were vaccinated in veterinary clinics. The third group, consisting of three boys, worked on designing a wheelchair-accessible door for students with physical disabilities at their high school. The teams and the projects each team selected are described in Table 3-1 (all names are pseudonyms).

During the pilot study, I acted as a mentor to the participants, facilitated group meetings, and conducted individual interviews with each participant. My role was not to direct what students should do for their project or how to solve the problem. My role involved only facilitating the bi-monthly group meetings, observing the group dynamics, and audio and video recording every meeting. Moreover, my role as a researcher was to bring experiences and perspectives from an engineering context to the study. I am a metallurgical engineer and I spent five years working for the mining and aerospace industries. I have been interested in engineering education for a long time, and I am interested in issues of social justice and educational equity for Latinos in STEM.

As a Latino engineer, it was important for me to engage Latino students in a project that allowed them to explore different perspectives of engineering. I tried to interact with the participants in every group discussion without interfering in their project or leading them to specific answers or solutions to their community-based problems. Some of the conversations were carried out in Spanish to let the participants express their ideas in a language they felt comfortable with. My interactions with the participants were not limited to research-related activities only but I also participated in other informal activities with them. For instance, I spoke to the participants at Noche de Ciencia – an evening event sponsored by the Society of Hispanic Professional Engineers where students and parents received information about scholarships and college admissions.

Table 3-1

Description of Groups for Pilot Study

Team	Team Composition	Community-Based Project
Team 1	Eduardo (male, 16 years old) Francisco (male, 17 years old) Miguel (male, 16 years old)	Design automatic set of doors for people with disabilities at their school
Team 2	Eva (female, 16 years old) Laura (female, 17 years old) Mateo (male, 15 years old)	Improve a local playground in their community
Team 3	Ana (female, 16 years old) Noemi (female, 17 years old) Silvia (female, 15 years old) Zoe (female, 17 years old)	Improve an existing device used by veterinarians to restrain feral cats during vaccinations

Several of the participants shared cultural and social similarities with me. In fact, two of the adolescents, Francisco and Miguel, came from the same geographical area where I grew up. This helped create *confianza*, or trust, between me and the participants, thus building the relationships which are extremely important for ethnographic research (Gonzalez et al., 2005). In addition, the participants were provided with an iPad to work on their projects and for research purposes during the duration of the study. There was no restriction on the number of web pages they could access or the applications they could download and use to work on the project.

Data Generation

Data sources included individual interviews, observations of group discussions, concurrent and retrospective protocols, and participants' products (a detailed description of data sources can be found in Chapter Four). Individual interviews were carried out every month with every participant in order to learn more about their interests, their families, work, school, neighborhood, and community. These semi-structured interviews with the participants were audio recorded and subsequently transcribed. During the monthly interviews, the participants were asked questions to further determine their funds of knowledge and how these funds of knowledge could be related to the engineering problems they selected. For instance, when Miguel mentioned a hydraulic lift at his workplace while he was talking during one of the group meetings, I used his comment as a basis for further questions about what he knew about the hydraulic lift at work and how that knowledge could have helped his group with their community-based engineering design problem. In other words, all questions asked during these meetings were open-ended questions intended to elicit information about their funds of knowledge and their connections to engineering design processes.

In addition, each group met twice per month in local community locations of their choosing and together we (the researcher and participants) visited their workplaces, local parks, and other community points of interest that were relevant to the problem that they had selected. The bi-monthly group meetings gave the participants a chance to talk about their projects, exchange ideas, brainstorm possible solutions, and engage in engineering design. The participants were given the opportunity to meet frequently (every two weeks) and decide on a community-based project as well as the approach they would use to solve such problem. It is important to mention that the objective of the pilot study was not to have a finalized artifact or product, but to investigate the funds of knowledge of the participants and use pilot study information to improve the protocol and design for the following year.

Retrospective and concurrent protocols (Ericsson & Simon, 1993; Smagorinsky, 1994) were used to gather data related to the participants’ funds of knowledge. During concurrent protocols, the participants were asked to articulate their thinking as they performed a task. For example, the participants conducted concurrent protocols as they searched for information on the internet using their iPads. As the participants were looking for information, they verbalized and explained what type of information they were looking for and why. The participants also engaged in retrospective protocols as they were prompted to reconstruct a process from memory. For instance, Francisco worked at a dairy farm and during an interview he was asked to explain the procedure used to milk cows at a dairy farm and how to use certain machinery during that process.

Finally, products generated by the research participants were collected, such as drawings they produced of their designs and records of the websites they visited during the information gathering stage of the design process. Other artifacts included final presentation put together by the participants, surveys, sketches, and prototypes. The purpose was not to evaluate their products but to use them as prompts for retrospective protocols.

Lessons Learned from Data Generation

As indicated before, the pilot study was used to become familiar with the dynamics of the project, analyze data collected to improve interview protocols, and become acquainted with strategies to reflect on how the research would be conducted for the full study. The following sections list some of the items that helped improve data generation and collection during the full study.

Interview Improvements

The research team – two graduate students and two faculty members – met frequently, usually every week, to discuss the progress on the pilot study. The data collected and the transcripts were used by the research team to elaborate new interview protocols and refine interviewing techniques. The interview protocols were changed to include questions that would broaden our definitions of funds of knowledge, and elicit the participants to think about the connections between their funds of knowledge and engineering activities (see Appendix A).

Also, the interviewing techniques were changed to include more follow up questions. For instance, one of the graduate students helping with the project was trained on how to look through previous interview transcripts and ask follow-up questions based on what the participants had said before. Thick descriptions (Geertz, 1973) were obtained from these improved interview protocols because the students were able to give not only broad descriptions of their funds of knowledge but also specific life events that described those funds of knowledge to a greater extent.

Group Meetings Improvements

Changes were made to the way interviews and group meetings were conducted in order to facilitate discussions relevant to the engineering problems. For instance, many of the participants frequently talked about the same items addressed during previous meetings, thus making tasks very repetitive and slowing down their progress. Therefore, in the full study we tried to begin each group meeting by asking them to summarize what they did last time and then set goals for that session.

In addition, some of the excerpts from group meetings and interviews were sent to external evaluators in order to get feedback on interview protocols. Although the feedback was very positive, the evaluators were concerned that participants did not have an awareness of what engineering was or what the engineering design process entailed. Therefore, the following year the participants were presented with a simple engineering design activity and were given a graphic organizer of the engineering design process (Achieve Inc., 2013).

Another change to the protocol was to have only one facilitator per group meeting. Although having different facilitators provided different perspectives during group sessions, it was decided that only one member of the research team would be present to facilitate group meetings. This change allowed only one person to lead the group meetings rather than having multiple facilitators, which we found confused the students.

Data Management Improvements

The research team realized that the way data were transcribed needed to be changed in order to make it easier to analyze. For instance, some of the interviews and group sessions were carried out in Spanish but our transcriptionists were not bilingual. Also, some of the transcriptionists were not naming each group member or were too slow transcribing. Therefore, a bilingual transcriptionist was hired to transcribe all interviews and group meetings that were in Spanish, and a fourth transcriptionist was hired to reduce the transcription turnaround time.

In addition, accessibility to the data was improved by obtaining a password protected network drive. The data were collected and stored in a secured place in order to give access to the research team members at any time. The centralized location of all data collected allowed for easy access to transcripts, videos, and notes.

Summary of Lessons Learned

The pilot study was used to improve data generation or collection the following year. The research team had an opportunity to use relevant information to develop techniques that improved the dynamics of the data collection. For instance, we learned that we could not let the adolescents set their own schedules so we created a schedule with a consistent meeting place each time. Thus, the pilot study was used to improve not only interview protocols, group meetings, and data management, but also group meeting dynamics and overall organization of the study.

Data Analysis

In addition to improving our data collection methods, we also used pilot study to generate a tentative set of codes that outlined the participants' funds of knowledge. I worked with Amy Wilson, PI on the project, to analyze the data using a modified version of constant comparative analysis (Corbin & Strauss, 2014). We first read and discussed previous literature in which categories of funds of knowledge were outlined, such as the works of Moje et al. (2004), Moll et al. (1992), and Barton and Tan (2009). Based on this literature, we developed a list of a priori codes we thought would appear in the data. A description of the a priori codes used during the pilot study is shown in Table 3-2.

Table 3-2

A Priori Codes Used for Pilot Study

Code	Definition	Example
Family Funds of Knowledge	Bodies of knowledge, skills, and practices derived from parents' work in and out of the home, transnational movements, and the environment	Working on a car with a parent, farming experience, or living in a different country during a period of time
Community Funds of Knowledge	Discourses of ethnic identity and social activism, commitment to social activism, and valuing the system of community	Working with the community to solve a problem or working at a local farmers market
Peer Funds of Knowledge and Discourse	Bodies of knowledge, skills, and practices derived from formal and informal interactions with peers	Peers helping each other during an activity or participating in activities mediated by adults
Popular Cultural Funds of Knowledge and Discourse	Bodies of knowledge, skills, and practices derived from mass media and popular culture	STEM-related information obtained from magazines, TV shows, or any other type of mass media

Although the initial analysis was done with four different codes, or categories, the codes were ultimately refined to reflect what was observed in the data (Saldaña, 2013). We read and discussed 10% of randomly selected data together as a team, and we compared and contrasted our *a priori* categories to what we found in the data. As we compared patterns in the data to the a priori codes, we realized that they needed to be modified and expanded. For instance, we found that *peer funds of knowledge* and *popular cultural funds of knowledge* were redundant. They were often assigned the same code because youth would engage in activities such as playing popular video games with other youth or discussing popular YouTube videos with other youth. Similarly, we also found that data excerpts which had been coded peer funds of knowledge were often coded community funds of knowledge. For these reasons, to avoid redundancy in coding, we decided to create a single category to describe community funds of knowledge where peer activities mediated by adults or other adolescents in formal or informal settings were present. The final "funds of knowledge" categories and subcategories of codes for the pilot study are shown in Table 3-3.

In addition to redefining the superordinate categories, we also refined the subcategories. For instance, *family funds of knowledge* were refined in order to contain four separate subcategories – workplace, health, household management, and international travel. In addition, popular culture funds of knowledge were clustered into a newly developed category that emerged from the data – *recreational funds of knowledge*. We observed during analysis that students relied on information they obtained from the internet, television shows, applets, and other types of mass media.

Table 3-3

List of Codes Obtained from Pilot Study Data Analysis

Category	Subcategory
Family funds of knowledge	Workplace
	International travel
	Health
	Household management
Community funds of knowledge	Community resources and organizations
	Volunteerism and community service
Recreational funds of knowledge	Digital technologies
	Popular culture

Although most of that information was related to popular culture, we decided to separate it into *popular culture* and *digital technologies* depending on how the students obtained the information (e.g., television shows versus applets). We observed that there was a difference between students just watching a TV show, such as Design Squad, where other people did tor demonstrated the work, versus actually participating in an applet where the participants engaged in design activities themselves, such as building, testing, and redesigning apple carts. To account for this difference, we coded popular culture as when participants viewed mass media, such as TV shows, but we coded digital technologies when students actually used technologies to influence the outcome of a product, such as applets or computer games.

Lessons Learned from Data Analysis

The pilot study provided the information necessary to improve data analysis the following year. Different techniques were identified as relevant for data analysis such as conducting analysis based on previously identified codes. For instance, we looked for patterns during the full study that were indicative of fund of knowledge based on the codes developed during the pilot study. Transcripts were analyzed to identify funds of knowledge already categorized during the pilot study but also to find new patterns.

Although most of the codes in the full study were consistent with those of the pilot study, a new set of codes was developed that applied to the data set. In fact, the following year a new funds of knowledge code emerged from the data and was described as *sports* under the recreational funds of knowledge category.

In addition, engineering codes were developed using the same techniques employed during the pilot study. A list of *a priori* codes was developed from the works of Atman et al. (2007) and Moore et al. (2014) in order to identify engineering design activities or engineering dispositions of the participants. We analyzed the data following the same techniques used during the pilot study and evaluated different data excerpts to identify the embedded engineering codes.

Summary of Pilot Study

The pilot study provided the information necessary to improve interview protocols, identify preliminary codes, and develop new research strategies for the project. The pilot study indicated that Latino students bring substantial funds of knowledge and experiences that are relevant to engineering practices and habits of mind. Although the pilot study focused primarily on funds of knowledge of the participants, the main focus in the full study was to identify the specific connections of their funds of knowledge to engineering design processes and practices. Guided by the information obtained from the pilot study, Chapter Four describes the methodology used for the current study.

CHAPTER 4

METHODS

This study seeks to understand the funds of knowledge of Latino high school students through participant observation, group discussion, and one-on-one interviews. In order to address each of the research questions, the research methods used for this study are described in the next sections. First, I explain the rationale for the use of a qualitative research approach for the present study. Next, I present the context of the current study where I included the characteristics of the environment, researchers, and participants, as well as the design of the study. Finally, I describe the data collection and data analysis methods for this study.

Study Design

Different approaches to educational research are used in engineering education including qualitative research methods that offer interpretive research quality (Borrego et al., 2009; Johri, 2014; Walther et al., 2013). According to Borrego et al. (2009), qualitative research can be used to answer questions that require "rich, contextual descriptions of the data, what is often called 'thick' description" (p. 56; cf. Geertz, 1973). The data obtained from qualitative research can provide information useful to answer the *why* and *how* questions that cannot be answered through quantitative research (Koro-Ljungberg & Douglas, 2008). Moreover, conducting qualitative research that is interpretive in nature informs the researcher about the perspectives of the participants. It is the purpose of interpretive research to study social phenomena and understand meaning-making from the participants' standpoint (Johri, 2014). Because the objective of this study is to understand the funds of knowledge of Latino students, interpretive research can be used to analyze the social interactions of the students, their perceptions, and sense-making of the world.

Johri (2014) argued that interpretive research "can alert us of the actual impact of proposed and attempted changes as opposed to the intentioned changes" (p. 554). It is the purpose of this study not to implement a change but to generate information regarding how positive changes can be made in engineering education. Thus, this interpretive research approach allowed for an investigation of the impact of the funds of knowledge framework before any type of intervention is implemented.

In this study, I used an ethnographic approach to qualitative research (Case & Light, 2014; Tedlock, 2000) to investigate the funds of knowledge of Latino high school students and how they use these funds of knowledge in engineering design. Ethnographic methods seemed appropriate for this investigation since ethnography and anthropological methods have been previously used to investigate funds of knowledge (Barton & Tan, 2009; Barton et al., 2008; Civil, 2002; Moje et al., 2004; Moll et al., 1992). Ethnographic methodologies can be used to understand the social, cultural, and environment surroundings of the participants (Case & Light, 2014). Ethnographic data brings a strong cultural lens to the study by describing and interpreting patterns of behavior, customs, and ways of life (Creswell, 2012). According to Hammersley and Atkinson (2007), ethnography is a method for data collection where

> the researcher participates, overtly or covertly, in people's daily lives for an extended period of time, watching what happens, listening to what is said, and/or asking questions through informal and formal interviews, collecting documents

> and artifacts – in fact, gathering whatever data are available to throw light on the issues that are the emerging focus of inquiry. (p. 3)

As indicated by Hammersley and Atkinson, the actions and accounts of the participants are studied in everyday contexts and the researcher takes an active role in the study. As the researcher in this study, I followed a group of fourteen Latino high school students for a period of nine months to investigate their funds of knowledge. I used different strategies such as group discussions, interviews, concurrent and retrospective protocols, and the collection of artifacts to study their funds of knowledge in everyday contexts.

Context of the Study

Throughout the course of one school year (9 months), I followed a group of fourteen Latino and Latina adolescents, ages 14 through 17, as they worked on a self-selected community-based engineering design problem. Latino students were recruited from two high schools located in a specific rural geographical region of the Western United States. This region is characterized by its farming and agricultural activity. The majority of the population worked in agriculture and farming-related occupations. Although the population is predominantly White, the Latino population in the area has been increasing over the past few years. Most of the families in the geographical region were from a low socioeconomic status. The area is also the home of a university with high research activity. Because the area is considered a "college town," a considerable portion of the population was transient due to students who move away after attending school.

Although the research participants were recruited from four high schools, only students from two different high schools were selected to participate in the study because they most fully met the selection criteria. The student body of both high schools was predominantly White. One of the high schools was a science, engineering, and technology-focused institution where students had the opportunity to take engineering courses. The high school had close ties to the university due to its proximity to the campus, and students often participated in extracurricular activities that were STEM-oriented. Some of these students' parents were well-educated, having completed high school and in some instances obtained a Bachelor's or advanced degree. On the other hand, the second high school was several miles away from the university campus. This high school did not offer engineering courses but students were required to take science and mathematics. By contrast, most of these students' parents had limited education and worked in farming and manual labor activities. The following sections describe how the students were selected, demographic characteristics of the participants and researcher, and the community-based projects selected by the students.

Research Participants

Two different clubs were targeted to introduce the research project to the Latino students and ask for volunteers: the Latino Discovery club and the Latinos in Action (LIA) club. The students who wished to participate in the project went through a selection process, which involved a 30-minute screening interview (see Appendix B for interview protocol). After the screening interviews, the students were selected using purposeful selection techniques (Gall et al., 2007) according to four different criteria. First, the students had to identify as part of the Latino ethnolinguistic group. Second, the students had to be enrolled in a local high school at the time of the study. Third, the students had to speak Spanish at home. Finally, the students interested in the project had to be enrolled in English as a second language (ESL) classes or had received ESL services for an extended period of time. Civil (2002) and Moll et al. (1992) indicated that language was part of students' funds of knowledge. Therefore, I worked with students whose first language was not English.

As part of the screening interview, the students were asked to describe their ethnic and educational backgrounds. Most of the students were born in the United States with the exception of five who were born in Latin American countries. The students also described their parents' ethnic and educational background as well as their parents' occupation. Regarding their educational backgrounds, all students were high school students and attended different high schools in the region, although many of their parents had not completed middle school or high school. This information was gathered to contextualize the data gathered in this study and in order to ascertain potential family and workplace funds of knowledge (Moje et al., 2004; Moll et al., 1992). A demographic description of the students is shown in Table 4-1.

Research Team

This study was conducted by a research team that consisted of four people: two Hispanic engineers, and two White university faculty members with expertise in education. In this section, I describe each person's background and their contributions to the project.

Hispanic engineers. As a former engineer, I took a lead role in conceptualizing and implementing the project. Over the past 10 years, I have been interested in

Table 4-1

Demographic Information of Study Participants

Participant	Engineering Courses Taken	Students' Country of Origin	Parents' Country of Origin		Parents' Occupation	
			Father	Mother	Father	Mother
Emiliano	Yes	U.S.A.	Mexico	Mexico	Farmer	Housewife
Patricio	Yes	Honduras	Honduras	Honduras	Engineer	Psychologist
Samuel	Yes	U.S.A.	Argentina	Mexico	Linguistics Professor	Linguistics Professor
Alejandra	Yes	U.S.A.	Mexico	Mexico	Landscaping	Housewife
Andrea[a]	Yes	Honduras	Honduras	Honduras	Doctor	Housewife
Paula	Yes	Honduras	Honduras	Honduras	Researcher	Housewife
Clarisa[b]	Yes	U.S.A.	Mexico	Mexico	Construction	Housewife
Carmen	No	U.S.A.	Mexico	Mexico	Absent[c]	Housewife
Dulce	No	U.S.A.	Mexico	Mexico	Absent[c]	Housewife
Felicia	No	Mexico	Mexico	Mexico	Farmer	Cook
Katy	No	U.S.A.	Guatemala	El Salvador	Mechanic	Housewife
Claudia	No	Mexico	Mexico	Mexico	Mechanic	Housewife
Sandra	No	U.S.A.	Mexico	Guatemala	Factory worker	Nurse
Sofia	No	U.S.A.	Mexico	Mexico	Mechanic	Housewife
Tomas	No	U.S.A.	Mexico	Mexico	Florist	Housewife

[a]Andrea was one of the original participants in the study after the screening interviews and selection process was finished. However, she was deported to Honduras and was replaced by another student at the middle of the study.
[b]Clarisa replaced Andrea after she was deported to Honduras.
[c]Carmen and Dulce did not provide information about their fathers.

engineering and engineering education. Most importantly, I have been interested in helping Latino students succeed in STEM-related fields. Like many other Latino students in the United States, I come from a low socioeconomic background and my native language is Spanish. Although I was born in the United States, I grew up in Mexico and spent my formative years in a small rural community. After fifteen years in Mexico, I migrated to the United States to finish my high school education and eventually pursue a degree in metallurgical and materials engineering. I am the first in my family to obtain a bachelor’s and master’s degree.

Subsequently, I worked for the aerospace and mining industries for 5 years gaining field experience. It was not until after a few years that I realized that engineering was not diverse. My experiences as a student and practicing engineer led me to the conviction that there were many factors that push away other Latinos from engineering. For example, I personally lived through the stigma of “deficit thinking” during high school. In college, I experienced the myth of meritocracy and the idea that engineering is only the application of mathematics and science.

My own cultural experiences as a Mexican American engineer have influenced the direction of my own research. Growing up in Mexico, I learned how to be resourceful from my farming experiences. Our farm was located far from our house in the main town. We had to get up early and prepare our lunch to take it with us because it was too expensive to go back and forth every day for lunch. We would spend the whole day at the farm but during lunch time our food was too cold. I remember watching my father use cow dung to heat up our food. I learned from observing my father that that cow dung could be used as a source of energy. Even though I didn’t scientifically know why cow dung could be used to heat up my food, I knew that it worked. I was exposed to the different bodies of knowledge and skills that emerged from our household practices. It is through these experiences that my interest in exploring culturally responsive engineering education practices emerged. I believe that the research I conduct will benefit a large number of Latino students in the United States and create changes in engineering education.

I have also used my own personal and cultural experiences to work through this study and connect with the participants. I was able to carry on conversations in both English and Spanish. My Mexican American background ignited the *confianza* with all the students. I was able to relate to the students in very specific ways because we shared some of the same experiences. My engineering background also created a sense of trustworthiness and the students felt comfortable asking for advice. I believe that being a Mexican American engineer opened up the opportunity to create a safe environment that resulted in students willing to share their experiences during our conversations.

I facilitated many of the group discussions and conducted several interviews with the participants. I also wrote several of the interview protocol questions and worked with a faculty member – experienced in qualitative research and adolescent literacy – to develop the codes for the data. These codes were used to analyze the whole data set. In addition, my role in the students' lives extended beyond the project to be a mentor. For example, one of the students was undocumented and I helped her find ways to apply for college. I also mentored another student that at the end of the pilot study decided to enroll in the engineering program at the local university.

The other researcher was a female master's student in environmental and civil engineering and held a bachelor's degree in civil engineering. She identified herself as Latina, was fluent in both English and Spanish, and was originally from a Spanish-speaking country in the Caribbean. She attended a bilingual school in her home country and received her college education in the United States. Because of her background, she was able to communicate and connect with the participants in the study. She facilitated and video or audio recorded several group discussions or individual interviews.

In addition, she was an active member of the Society of Hispanic Professional Engineers at the local university. She was the president of the organization and was actively involved in the community. One of her goals as president of the organization was to reach out to the Latino community and engage students in engineering activities. Her role as a researcher also went beyond the scope of the project. She mentored some of the students and helped them get connected to other members in the community, including other Latino engineers. She was very passionate about getting Latino engineers into the profession as well. After the study concluded, she was accepted into a doctoral program in engineering education but deferred for a year to gain experience as a practicing engineer.

University faculty members. The second researcher was a White female assistant professor of literacy at the local university. She has published research on the in-school and out-of-school literacy practices of linguistically and culturally diverse students. She also facilitated different group discussions or individual interviews. Also, she was actively involved in the recruitment of participants and contacting the high schools. Her main interest was to investigate the students' funds of knowledge as well as their literacy practices. She conceptualized the initial study and procured funding for it. Together, we elaborated and improved the interview protocols and developed the data analysis codes.

The last member of the team was a White male researcher with experience in engineering and technology education. He was involved in the process of elaborating more detailed questions for the interview protocols. He provided advice on how we could improve the students' experiences so that they were more authentic to engineering. He also managed and organized the data – transcripts, notes, audio and video files, and images – that were later uploaded to a secure server.

Community-Based Engineering Design Problems

The students were divided into four different teams. Each team selected a problem in their community they wanted to address. These problems were characterized as ill-structured problems because they were "not constrained by the content domains being studied in classrooms" (Jonassen, 2014). For example, the community-based problems selected by the students were dynamic, required collaboration, involved multiple solutions, and the constraints, both engineering and non-engineering, were identified by the students themselves (Jonassen, 2014; Jonassen et al., 2006). The main objective was to observe how students used their funds of knowledge as they worked on their problems, not to have a finalized solution.

Three of the teams focused on solutions that could help disadvantaged communities. Team 2 worked on a water catchment system that could be used by impoverished people in Honduras. The devastation left by Hurricane Mitch affected many people in Honduras and a portion of the population had limited access to water. It was the purpose of Team 2 to provide an inexpensive and effective way for people in that region to collect water. Team 3 worked on designing a playground swing that could be used by people in wheelchairs. Team 4 designed a headrest for a tub-based shower chair that would be used by individuals with a specific type of muscular dystrophy. Team 1, by contrast, did not necessarily focus on a design that would help a disadvantaged community. Instead, they designed a shoe that would be water resistant, have good traction, and could be worn to play and run outside during the winter. The composition of the teams and descriptions of the problems they addressed is shown in Table 4-2. For the purposes of clarity, throughout the rest of the dissertation I will refer to these teams as the Shoe Team, the Water Catchment Team, the Wheelchair Swing Team, and the Headrest Team, respectively.

As indicated in Tables 4-1 and 4-2, the original participants in the Water Catchment Team included Alejandra, Andrea, and Paula. However, after the study had initiated, Andrea was deported to Honduras and she was replaced by Clarisa. Although Clarisa was not selected after the initial screening interview and selection process, she was considered a strong candidate for the study. This was the only instance where one of the participants had to be replaced due to external factors. The dynamics of the group after Andrea left the team did not change, and Clarisa worked with the team for the rest of the study.

This study did not look into gender differences; therefore, there was no emphasis on gender composition of the teams. The groups were organized so that students attending the same high school could work together. Therefore, geographical location played an important role when creating the groups.

Table 4-2

Description of Teams and Community-Based Design Problems

Team	Team Composition	Community-Based Project
Team 1	Emiliano (male, 17 years old) Patricio (male, 14 years old) Samuel (male, 16 years old)	Design a water-resistant and good-traction shoe for playing and running during the winter
Team 2	Alejandra (female, 15 years old) Andrea[a] (female, 14 years old) Paula (female, 16 years old) Clarisa[b] (female, 14 years old)	Improve a water catchment system for underprivileged communities in Honduras affected by hurricane Mitch
Team 3	Carmen (female, 17 years old) Dulce (female, 17 years old) Felicia (female, 16 years old) Katy (female, 16 years old)	Improve a playground swing for children in wheelchairs
Team 4	Claudia (female, 17 years old) Sandra (female, 16 years old) Sofia (female, 17 years old) Tomas (male, 17 years old)	Improve headrest on a tub-based shower chair for children with muscular dystrophy

[a]Andrea was one of the original participants in the study after the screening interviews and selection process was finished. However, she was deported to Honduras and was replaced by another student at the middle of the study.
[b]Clarisa replaced Andrea after she was deported to Honduras.

It is also important to mention that the problems selected by the students were heavily influenced by personal experiences. For example, the Shoe Team chose a project that involved designing shoes to be used for athletic purposes because two of the team members, Patricio and Samuel, were student athletes. Both students played soccer and were very interested in sports. The third team member, Emiliano, was excited by the project because he loved fashion design and wanted to make a winter shoe that would be fashionable for young adults. The Water Catchment Team addressed a problem that was heavily influenced by the personal experiences of two of the students – Paula and Andrea. Both students were from Honduras and they had observed how people were affected by Hurricane Mitch. Although Alejandra was not from Honduras, she also cared about the problem because she had lived in an area of Mexico where obtaining water was often problematic.

All four students in the Wheelchair Swing Team had previously volunteered as tutors or assistants in the special education program at their school and were interested in providing a new form of entertainment to the students with physical disabilities. Finally, Tomas, one of the members of the Headrest Team, had two brothers with Duchenne Muscular Dystrophy – a specific type of muscular dystrophy that causes extreme muscular degeneration and ultimately results in an early death. The team decided to work on the shower chair headrest because Tomas indicated that it was complicated to bathe his brother while holding his head straight due to his brother's physical condition.

Each group met twice per month in local community locations of their choosing and together we (the researcher and students) visited their workplaces, local parks, and other community locations that were relevant to the problem that they had selected. As indicated before, the study took place in a rural environment where agriculture and farming were some of the main activities. There were different milk and meat processing plants that employed a large number of people in the area. These locations were part of the settings where observations and collection of data took place.

Students were encouraged to go to their communities to identify a problem they might solve and find information that was relevant. In addition, the students were provided with an iPad, engineering notebooks, and a wireless Internet connection (if necessary) for research purposes during the duration of the study. The information collected from different sources in their community or the Internet provided an insight to the funds of knowledge of the students, how they navigated through their social networks, and how they created new knowledge as described by Moje et al. (2004).

The bi-monthly group meetings were used as a venue where students were able to discuss their engineering design problems. Students were encouraged to talk about their designs, challenges encountered, constraints, or limitations of their project. I served as a moderator for the discussions and facilitated the meetings. The data collected during these meetings highlighted how students used and applied their funds of knowledge when trying to solve the community-based problem.

Finally, the students participated in one-on-one interviews every month with the researchers. The purpose of these interviews was to understand the funds of knowledge of the students (Barton & Tan, 2009; Moje et al., 2004; Moll et al., 1992) and learn more about the students. The interviews are necessary in order to "obtain descriptions of specific incidents by asking respondents to particularize" (Weiss, 1994) on general descriptions provided during previous interviews or group meetings.

Data Collection

The intent of the project was to obtain concrete instances rather than generalized accounts (Weiss, 1994) from the participants with the aim of documenting the students' funds of knowledge and how they applied those funds to the engineering design processes. Data were collected through video and audio recordings and field notes. The first type of data came from the recorded bi-monthly meetings and monthly one-on-one interviews with the participants. The group meetings were also audio and video-recorded as the students collected data in their communities or discussed the engineering design problems. The data were transcribed, and transcripts of all previous meetings were read in advance in order to create protocols for upcoming group meetings and individual interviews (Glaser & Strauss, 1967). The transcripts were analyzed before the next interview or group meeting so that the research team could adjust the protocol instruments.

The types of data collected in ethnographic approaches to qualitative research include participant observations, interviews, and artifacts (Creswell, 2012). For this study, data sources included individual interviews, observations of group discussions, retrospective and concurrent protocols, and student products. It is important to mention that all questions included in the protocols were reviewed by experts in the fields of qualitative research, engineering education, and engineering. The two experts included a professor with research expertise in funds of knowledge of culturally and linguistically diverse students, as well as a professor with several years of research experience in engineering design in engineering education contexts. The individuals providing feedback on the protocols evaluated the cultural responsiveness of the interview questions, thus adding to the validity of the protocols (Walther et al., 2013).

Individual Interviews

An initial (see Appendix C for initial interview protocol) and final (see Appendix D for final interview protocol) one-on-one interview was conducted with every participant, in addition to monthly interviews (see Appendix E for ongoing interview protocol), in order to establish a relationship between the students and the researchers and build a certain level of "*confianza*," or trust (Moll et al., 1992). The interviews, which ranged from about 30-60 minutes in length, were audio-recorded. When necessary, these interviews were also video-recorded, such as when the participants used gestures to explain an image they had drawn.

In the initial interview, participants were asked questions about their background, family, school, work, friends, households, and neighborhoods. In the monthly one-on-one interviews, questions were asked to further determine the funds of knowledge that students used to address the engineering problems. For instance, we used the participants' previous answers as the basis for further questions about how their knowledge might have helped the group solve the engineering problem. All questions asked during these meetings were open-ended questions intended to elicit information from the students about their funds of knowledge, social networks, and engineering design processes.

The interviews took place at local schools or libraries. The initial interviews were used to learn more about the students' backgrounds and life histories (i.e., Could you tell me a little about yourself? Could you tell me about your family? What languages are spoken at home? Could you tell me more about your community?), which provided important information about their funds of knowledge. The ongoing interviews were used to ask questions regarding the students' social practices (i.e., Do you have a job? What problems do you see in your community? Have you talked to your parents, family members, or neighbors about this project? Who can you talk about this problem? Have you been able to receive any useful information that would help you solve this problem?).

Although the interviews were semi-structured and a protocol was developed, most of the interview questions were based on findings from previous interviews or group discussions (Rubin & Rubin, 2012). The information provided by the respondent was always monitored in order to get as much information as the respondent could supply (Weiss, 1994). Overall, students were asked questions regarding their family, their community, social exchanges, challenges faced, social resources used, and observations they had made to provide solutions to the engineering design problem. All questions were open-ended intended to elicit information about their funds of knowledge, social networks, perceptions, and engineering design processes.

Observations

In addition to conducting individual interviews, the research team conducted observations during group meetings. Each group met twice per month, with each meeting lasting between 90 minutes and two hours. We held the group meetings in different places in the community and sometimes at the university. One crucial part of the observations included video recording the meetings and making observations of the students' practices and interactions. For example, some of the students gathered information from community members and organizations and used that information in their problem solving activities. Community members included a professor of civil engineering, employees at a nursing home, and a student proficient in solid modeling that helped the Wheelchair Swing Team and the Headrest Team create three-dimensional models of their designs. In addition, we also observed students when they conducted internet searches or when they engaged in "hand-on" activities such as measuring or using tools to create different products.

During these meetings, the group members identified a problem in their community, discussed how they could provide solutions to that problem, and generated ideas for possible solutions during subsequent meetings. As described previously, I facilitated the group meetings and my role was to ask open-ended questions to prompt discussion if the students seemed unsure of what to do next. For instance, questions such as, "What do you think of those ideas?" or "How can you improve that?" were asked in order to prompt discussion and encourage students to apply engineering design processes.

I also asked other questions to elicit the participants' funds of knowledge (i.e., What do you know about it? Have you had to use it before? Why do you think it works the way it works?) and how they could apply those funds of knowledge to solve the engineering design problem (i.e., Have you ever had to solve a problem that was similar to this problem? Can you explain to me how this works? Can you show me what you did when you solved that problem? Do you have any ideas for making a new device?). A list of questions used to identify how students applied their funds of knowledge to the engineering design process is shown in Appendix F.

Retrospective and Concurrent Protocols

Two types of think-aloud protocols were collected during the study: *concurrent*, in which a participant was asked to think aloud during the process of completing a task, and *retrospective*, in which a participant completed components of the task, or the whole task, and then was prompted to reconstruct the process from memory (Ericsson & Simon, 1993; Smagorinsky, 1994). The purpose of these protocols was to ask the students to explain what they were thinking during specific tasks and relate their think-aloud processes to engineering. For example, we asked students to explain why a particular material selection was made and to guide the researcher through the selection process. This process also allowed the researcher to investigate how different artifacts could be used as prompts to encourage students to reconstruct processes from memory.

Gero and Tang (2001) argued that concurrent protocols are usually used when focusing on the process-oriented aspects of design (cf. Simon, 1996). This method allows the participants to perform a task while simultaneously verbalizing their thoughts. For instance, the participants in this study thought aloud as they played a game related to engineering, such as building an apple cart, on the iPad. Then the participants verbalized and reflected on their actions as they played the game. They evaluated different solutions depending on constraints, or they analyzed trade-offs. Through this data collection method, I was able to determine how a fund of knowledge, such as digital technologies, could be connected to engineering.

In retrospective protocols the participants retrieve cognitive processes and reveal the information they recall (Gero & Tang, 2001). For example, students usually drew sketches of their designs and they were asked to describe the thought process that went into it. The participants were asked follow-up questions to obtain thick descriptions from the students. This approach was used to investigate what funds of knowledge the participants drew from while they performed the task.

Student Products

Student products or artifacts were collected during and after the study. These products included representations generated during the design process (i.e., photographs, drawings, computer generated images, objects, storyboards, sketches, etc.), drafts of final designs, surveys, pictures taken during field trips, or any other relevant artifacts. At the end of the study, the students were asked to present a final report of their project to a client, which was also considered a student-generated product. It is important to mention that the purpose of this study was not to have a finalized artifact or product which approximated the solutions of professional engineers in terms of overall quality, but to observe and determine how the students used their funds of knowledge to solve engineering design problems. We collected these artifacts with the purpose of using them as a basis for the retrospective protocols, as described previously.

Data Analysis

Due to the nature of the study, data collection and data analysis often took place simultaneously. All files including video recordings, audio recordings, pictures, and transcripts were saved in a password-protected computer. Approximately one hundred and fifty hours of video and audio recordings were collected throughout the study. The transcripts obtained from every video and audio recording were subsequently analyzed using the qualitative data analysis software NVivo 10, which helps to manage, organize, and analyze text and multimedia information (QSR International, 2012). Analysis of the data involved a modified version of constant comparative analysis (CCA) (Corbin & Strauss, 2014). This method of analysis combines category coding with simultaneous comparison of all incidents observed as well as simultaneous comparison across categories. Although CCA was originally developed as an extension of 'grounded theory' (Glaser & Strauss, 1967), in which the researchers allegedly have no preconception of the categories that they will find, the proposed modified version of CCA was shaped by a theoretical model and previous research connecting adolescents' everyday Discourses to science Discourses (Barton & Tan, 2009; Moje et al., 2001).

The predefined codes obtained from the literature review and from the pilot study served as the basis for data analysis and the development of new codes. New codes emerged during the study through systematic and careful analysis of the data. Even though some codes had been already identified from previous works, some categories were inductively collected from the data until a point of saturation was reached and no new codes emerged (Strauss & Corbin, 1990). Two interrelated types of codes were developed: funds of knowledge codes, and engineering codes. The following sections describe these two overarching categories of codes in more detail.

Funds of Knowledge Codes

As described in Chapter Three, "funds of knowledge" codes had been developed in the pilot study. These codes included three major categories: (a) family funds of knowledge, (b) community funds of knowledge, and (c) recreational funds of knowledge. These categories also contained clusters of data that required further refinement into subcategories (Saldaña, 2013). These subcategories were connected to the three major categories through a process of axial coding. Although most of the codes from the pilot study applied to the subsequent study, the new code *sports* emerged from data analysis as a subcategory of recreational funds of knowledge. This code was not observed during the pilot study. Table 4-3 describes the community funds of knowledge category and its corresponding subcategories and their descriptions. Table 4-4 includes the recreational funds of knowledge and a description of each subcategory within that category. Finally, Table 4-5 describes the family funds of knowledge and the subcategories that emerged from the data set after axial coding.

Table 4-3

Community Funds of Knowledge Subcategories and Corresponding Descriptions

Subcategory	Definition
Community resources and organizations	Bodies of knowledge, skills, and/or practices derived from experiences with community groups.
Volunteerism and community service	Bodies of knowledge, dispositions, skills, and/or practices associated with serving others.

Table 4-4

Recreational Funds of Knowledge Subcategories and Corresponding Descriptions

Subcategory	Definition
Popular culture	Bodies of knowledge, skills, and/or practices derived from viewing, reading, or listening to mass media and popular cultural texts (e.g., TV shows, YouTube videos).
Sports	Bodies of knowledge, skills, and practices derived from participating in organized or informal sports teams or communities.
Digital technologies	Bodies of knowledge, skills, and practices derived from interacting with digital technologies (e.g., applets, video games).

Table 4-5

Family Funds of Knowledge Subcategories and Corresponding Descriptions

Subcategory	Definition
Workplace	Bodies of knowledge, skills, and practices gained through the adolescents' or their relatives' employment.
Health	Bodies of knowledge, skills, and practices related to improving, maintaining, managing, or repairing physical or mental health.
International travel	Bodies of knowledge, skills, and practices derived from living in another country and/or traveling to another country.
Household management	Bodies of knowledge, skills, and practices derived from maintaining basic family functions or from constructing, managing, or improving a household, a yard, or the items within them.

The following excerpt from an interview with Emiliano will illustrate how coding for funds of knowledge was done. Emiliano indicated that his mother taught him how to sew, and he used those sewing skills to fix his own pants. Emiliano said,

> I've tried fixing pants but it didn't work very well because after a while they sort of lose their shape. But it depends on what kind of needle and thread you use. If it's too big, it leaves holes and it doesn't look very good any way. But if your thread is too fine, it's just going to break anyway. So it just kind of depends on what kind of needle and thread and how you sew it together. When I was working on those [the pants], the needle didn't work very well, so yeah.

Emiliano described skills related to a specific home practice (sewing) that he learned from his mother. He learned about the type of needle and thread that could be used for different circumstances. Later during the interview, Emiliano mentioned that he learned how to fix his pants because his mother did not have money to buy a new pair of pants for him. Household knowledge involved not only maintenance of the home but also dealing with changing economic circumstances (Moll et al., 1992). The knowledge gained from this home experience was considered a family fund of knowledge. This excerpt was eventually coded, more specifically, into the household management subcategory because Emiliano acquired a set of knowledge and skills derived from home practices used to repair items. He later applied this knowledge to his engineering design project when he explained to his teammates that in order to fabricate the shoe they needed to consider the characteristics of the materials to be sewn together. For instance, he indicated that it would be difficult to sew together three different fabrics with very different physical characteristics.

Engineering Codes

In addition to the funds of knowledge codes, different engineering-related codes and patterns emerged from the data. Two different engineering-related categories were obtained: (a) codes related to engineering design processes; and (b) codes related to bodies of knowledge, dispositions, and habits of mind relevant to engineering. The works of Atman et al. (2007), Moore et al. (2014), and the National Assessment Governing Board (NAGB) (2013) provided the research team with *a priori* codes that were applied to the data. Moore et al. and the NAGB provided a conceptual framework that included the defining characteristics of engineering and concepts required for success in engineering. Atman and colleagues described three design stages and their corresponding design activities. These design activities and design stages were consolidated to describe the codes emerging from the data and later used to explain the observed engineering design processes. Consolidating previously established codes is one way to create new codes that can be used to describe salient attributes from the data (Saldaña, 2013). The final lists of engineering codes are in Tables 4-6 and 4-7.

We first applied a "funds of knowledge" code to each excerpt, and we then coded that data excerpt with engineering design processes or defining characteristics of engineers. The following example is used to describe how one excerpt from an interview with Samuel resulted in funds of knowledge codes as well as engineering codes. Samuel used to be a competitive skier and he learned different concepts from his experiences. Samuel talked about what he learned from skiing:

> The thing I probably learned the most was with the edges concept. So with the edges of the skis with the slalom ones, they have the most flexibility out of all the skis, which provides a lot of the quick maneuvering. And they're also very light. But the main thing is they're a little shorter and they're more curved at the top. But when they're curved, they kind of have like a little indent outwards. And that just helps so like when you're turning, you can just like turn a little bit quicker. And then the giant slalom, it's more rounded out, I guess. And then with the Super G ones - I never did Super G, Super G was for the older people – those are very, very long and stable. Like heavy skis. So like it's not a lot of turning; it's more just how fast you dare go.

This excerpt was coded as *recreational funds of knowledge: sports* because Samuel described his experiences with being on a ski team and knowledge learned from those experiences. In addition, this excerpt was coded as *systems thinking* because Samuel identified how different physical variables (e.g., weight, length, curvature of the skis)

Table 4-6

Codes Related to Engineering Design Processes

Code	Definition
Problems definition	Identify client's needs or wants; identify areas for improvement of current devices or systems; identify audience for product; or identify criteria and constraints.
Information gathering	Consult others regarding aspects of the problem; look for information on the Internet; or observe, manipulate, or test existing devices or systems to determine areas for improvement.
Generating ideas	Generate potential solutions to part or all of the problem(s); or identify possible steps that the team needs to take in order to solve the problem or produce the design.
Modeling	Sketch/label representations of ideas; use mathematics to calculate different aspects of the design; or build a physical prototype.
Evaluating solutions	Evaluate a solution or solution element based on one or more criteria or constraints; weigh competing criteria and constraints or constraints and consider trade-offs in attempts to optimize design; or evaluate solution or solution elements based on physical or virtual tests.
Communication	Communicate final design to client through writing, drawing, and/or a physical model; conduct market research to determine best approach for selling device.
Realize solution	Construct or improve an existing physical device or product; implement a series of processes that solves a problem or meets a need; select a solution or solution element.

Table 4-7

Codes Related to Bodies of Knowledge, Dispositions, and Habits of Mind Relevant to Engineering

Code	Definition
Scientific or mathematical knowledge	Apply knowledge of scientific or mathematical facts or principles to a problem.
Systems thinking	Consider multiple interconnected variables, including social, physical, and temporal variables; analyze how changes to one variable might influence other components in the system.
Production and processing	Apply knowledge of materials; costs; and/or sequential acquisition processes, production processes, or distribution processes in order to maximize efficiency in the creation or distribution of a product, or in order to maximize profits gained from a product.
Ethical considerations and empathy	Demonstrate a commitment to the well-being of animals, the environment, or vulnerable human populations; consider a product or system’s impact from the perspective of somebody living under different conditions than oneself.
Teamwork	Communicate well with others as a team moves toward accomplishing a common goal; divide roles based on individuals’ expertise or characteristics in order to efficiently complete a project.
Use of tools	Use communication tools to generate or communicate design ideas; use measuring tools; explain how construction tools are used to produce or install a design.

may influence the performance of a system or other components within the system (e.g., how physical characteristics may affect maneuvering). Samuel indicated that slalom skis are lighter and shorter to allow quick maneuvering as opposed to Super G skis which are heavier and longer to allow the skier to go downhill more quickly.

Ensuring Research Quality

The term “quality” is often used in qualitative research as an alternative to the term “validity and reliability” in quantitative research (Southerland, Gadsden, & Herrington, 2014). Although the term ‘quality’ holds different meanings to different researchers, it generally means that different researchers who look at the same data set could draw similar conclusions because a rigorous, detailed, consistent, and transparent method was used to collect and analyze the data (Freeman, DeMarrais, Preissle, Roulston, & St. Pierre, 2007). Johri (2014) argued that interpretive research is exceptionally useful but there are standards of practice that can be followed to ensure the quality of the information obtained from this type of research.

In order to achieve credible findings (Lincoln & Guba, 1985), or theoretical validation (Walther et al., 2013) and methodological soundness (Creswell & Miller, 2000), I used different techniques such as gathering information from different sources and peer debriefing for communicative validation (Walther et al., 2013). Triangulation was obtained by the use of different data sources, which were used to capture multiple points of view and to look for different patterns in the data (Lincoln & Guba, 1985; Walther et al., 2013). The integrity of the data analysis was maintained through different data sources (interviews, observations, retrospective and concurrent protocols, and student products) for triangulation and theoretical validation (Walther et al., 2013). In addition, pragmatic validation was obtained by gathering data in natural settings, such as the community, while procedural validation was reached through interview protocols that elicited specific information regarding funds of knowledge (Walther et al., 2013).

A percentage of the data set (10%) was analyzed jointly with one member of the research team, and new codes were developed while mutually agreeing on each code (Smagorinsky, 1994). Agreement of the codes reached by the two researchers was 92%, thus indicating that they were reliable (Tan, Calabrese-Barton, Kang, & O'Neill, 2013). Data audits were conducted by an external panel, in which they read and discussed individual data excerpts—including the process and product behind the analysis—and confirmed that the initial analysis of the data seemed credible to them based on their familiarity with the project. These data audits were conducted by a professor with expertise in engineering education and engineering design, and a professor with research experience in language and literacy and Latinos' funds of knowledge in sociocultural contexts.

In addition, peer debriefing was used to confirm data interpretation and correct use of methods (Lincoln & Guba, 1985). Peer debriefing in this study included constant conversations and weekly meetings with the other three researchers and the data audits performed by two experts in engineering and Latinos' funds of knowledge research. The weekly meetings offered an opportunity to constantly review interview protocols and transcripts. The external reviewers provided feedback that helped improve the questions in the interview protocols to make them more culturally responsive. All data collected for the study was protected by the researcher as well as the integrity and identity of all participants.

Summary of Methods

This ethnographic study investigates the funds of knowledge of Latino high school students and how they use these funds of knowledge in engineering design. Analysis of the data involves a modified version of constant comparative analysis (CCA) shaped by a theoretical model and previous research connecting adolescents' everyday Discourses to science Discourses (Barton & Tan, 2009; Moje et al., 2001).

The predefined codes obtained from the literature review and the works of Barton and Tan (2009) and Moje et al. (2001) served as the basis for data analysis. The data collected from the pilot study served to improve the interview protocols and for the development of new codes related to funds of knowledge (Tables 4-3 through 4-5) and to develop engineering-related codes (Tables 4-6 and 4-7). Participant observation, bi-monthly group discussion, retrospective and concurrent protocols, and monthly one-on-one interviews were conducted. Video and audio recordings, as well as field notes, were used to record students' collection of data in their communities and their discussion of engineering design problems.

CHAPTER 5

FINDINGS

This chapter addresses the first research question: “What engineering-related funds of knowledge do Latino high school students have?” In this case, the term *funds of knowledge* describes the historically accumulated and culturally developed bodies of knowledge and skills essential for household or individual functioning and well-being (Moll et al., 2005; Velez-Ibañez & Greenberg, 1992). The findings presented in this chapter describe the bodies of knowledge and skills that the participants possessed that could potentially enhance their engineering design activity. Additionally, I investigated how those funds of knowledge were used by the participants to solve the community-based engineering design challenge, thus addressing the second research question: “How are these funds of knowledge used to address a self-selected community-based engineering design problem?”

As mentioned in the previous chapter, the data were analyzed using a modified version of Constant Comparative Analysis. From this analysis, different categories and subcategories were developed (Saldaña, 2013). Three main categories related to funds of knowledge were obtained from the data analysis: (a) family funds of knowledge, (b) community funds of knowledge, and (c) recreational funds of knowledge. Every category contained different subcategories clustered within each funds of knowledge category, as shown in Table 5-1. The table shows the main category on the left and the subcategories that emerged from each category on the right.

Table 5-1

Funds of Knowledge Categories and Subcategories Obtained from Data Analysis

Category	Subcategory
Family funds of knowledge	Workplace
	International travel
	Health
	Household management
Community funds of knowledge	Community resources and organizations
	Volunteerism and community service
Recreational funds of knowledge	Digital technologies
	Sports
	Popular culture

An analysis indicated that engineering codes, described in Chapter Four in Tables 4-6 and 4-7, were embedded in the participants' funds of knowledge. The following sections describe how the adolescents applied their funds of knowledge to find alternative solutions to their community-based engineering design problems. Every description of the funds of knowledge subcategories is followed by a brief discussion regarding engineering codes embedded in those funds of knowledge. I have divided this chapter into three main themes, which contain a discussion of every funds of knowledge category and corresponding subcategories, and different selected excerpts from the data that show the presence of such funds of knowledge. I then describe how each data excerpt connects to engineering design processes, dispositions, and thinking.

Every category was analyzed to identify the number of instances the participants mentioned something related to the three main categories and subcategories of funds of knowledge (*N* = 388). As shown in Figure 5-1, family fund of knowledge were the most prominent funds of knowledge mentioned by the s. Figure 5-2 separates these funds of knowledge into subcategories. As indicated by Figure 5-2, most instances of funds of knowledge derived from household management, workplace, and international travel subcategories. These subcategories are part of the family funds of knowledge category, thus indicating that home-based funds are important for the participants and could be useful funds to help Latinos create "bridges" between everyday practices and engineering practices (Gonzalez et al., 2005; Moje et al., 2004; Moll et al., 1992).

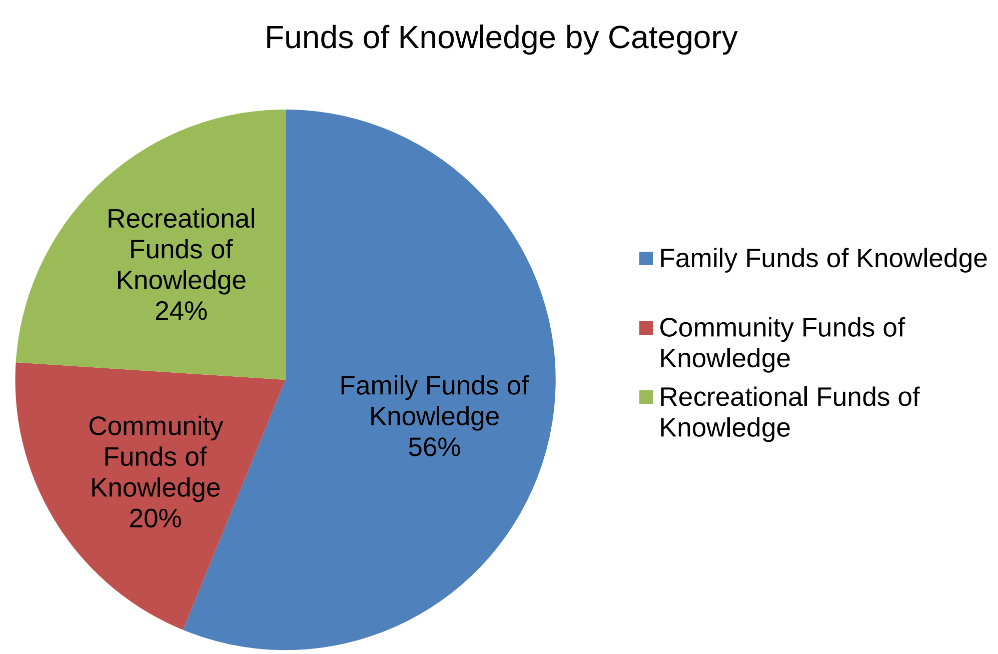

Figure 5-1. Incidence of funds of knowledge by category (*N* = 388). This figure represents the proportion of each category with respect to the total number of instances when participants mentioned funds of knowledge.

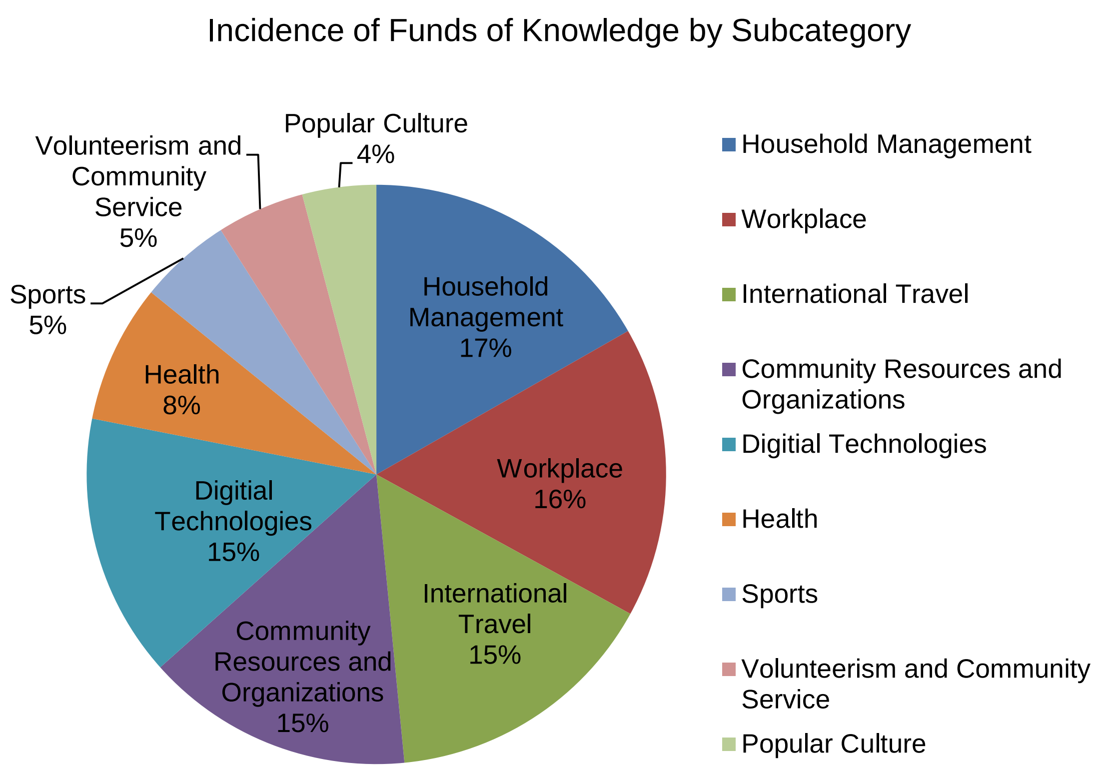

Figure 5-2. Incidence of funds of knowledge by subcategory (*N* = 388). This figure represents the proportion of each subcategory with respect to the total number of instances when participants mentioned funds of knowledge.

Categories and Subcategories Related to Funds of Knowledge

In this section I present the categories and subcategories related to funds of knowledge that emerged from the data collected. These codes were developed using a modified version of Constant Comparative Analysis and with *a priori codes* (Table 3-2 in Chapter Three) obtained from the works of Barton and Tan (2009), Moje et al. (2004), and Moll et al. (1992). Although *a priori codes* were used to develop the first set of codes from the pilot study, the codes were eventually refined until a complete set of codes was achieved through data analysis and consolidation of previously established codes (Saldaña, 2013). The next sections describe the subcategories, listed in order of most frequently mentioned funds of knowledge to least frequently mentioned funds of knowledge. Specifically, I start with family funds of knowledge subcategories, followed by the subcategories included in recreational funds of knowledge, and finally a description of the subcategories comprising community funds of knowledge. Each subcategory description also shows how these funds of knowledge connect with engineering codes.

The purpose of the following sections is to describe how the engineering-related codes are connected to funds of knowledge. These excerpts serve as telling cases and represent "identical general theoretical principles" similar to those exhibited by other participants (Mitchell, 1983, p. 192). Telling cases allow for a "detailed examination of an event" that functions to "stimulate generalizations and induce theoretical interpretations about contextual circumstances" (Rex, 2001, p. 295). By analyzing the data in these excerpts, I provide "thicker description" of the participants' funds of knowledge from their perspective and their situated meaning-making (Geertz, 1973; Johri, 2014).

Family Funds of Knowledge

Four main subcategories of family funds of knowledge emerged from this study – workplace, international travel, health, and household management. Overall, the subcategories encompass funds of knowledge that revolved around the bodies of knowledge, skills, and practices obtained by the participants from their own experiences in and out of the home, as described by Gonzalez et al. (2005), Moje et al. (2004), and Moll et al. (1992). Everyday funds of knowledge were important sources of information not only for the participants' individual functioning but also for approaching and solving the community-based engineering design problem. Although variation of family funds of knowledge among adolescents existed, all participants drew from workplace, health, and household management funds of knowledge, usually in local spaces. Moje et al. (2004) argued that family funds of knowledge are “diverse and far ranging,” occurring not only in local spaces but also in transnational movements (p. 52). Therefore, *international travel funds of knowledge* was added to the list of family funds of knowledge as a separate category because many of the participants were involved in transnational movements or had spent prolonged amounts of time outside the United States.

Table 5-2 indicates the number of instances that each participant mentioned family funds of knowledge (n = 218). Although some of the participants were assigned a higher number of codes, or instances when they mentioned family funds of knowledge, than others, it does not mean that participants with lower number of codes possessed fewer funds of knowledge. The number of codes only represents how frequently they mentioned an event or experience that was related to one of the four subcategories in the family funds of knowledge category. In the case of Clarisa, for example, who replaced Andrea after she was deported to her home country, the number of codes may be lower because she only participated in the project for three out of nine months. Thus, the number of codes may be influenced by factors such as participation during group meetings or the descriptions given by the participants during individual interviews. A pie chart illustrating the percentage of instances when participants mentioned any of the family funds of knowledge subcategories is shown in Figure 5-3.

The four subcategories presented in this section – workplace, international travel, health, and household management – represent the findings related only to family funds

Table 5-2.

Number of Instances When Each Participant Mentioned Family Funds of Knowledge (n = 218)

Participant name	Number of instances
Sandra	30
Katy	25
Paula	24
Claudia	21
Sofia	18
Emiliano	17
Tomas	16
Samuel	14
Andrea	14
Alejandra	10
Patricio	8
Clarisa	7
Carmen	6
Felicia	5
Dulce	3

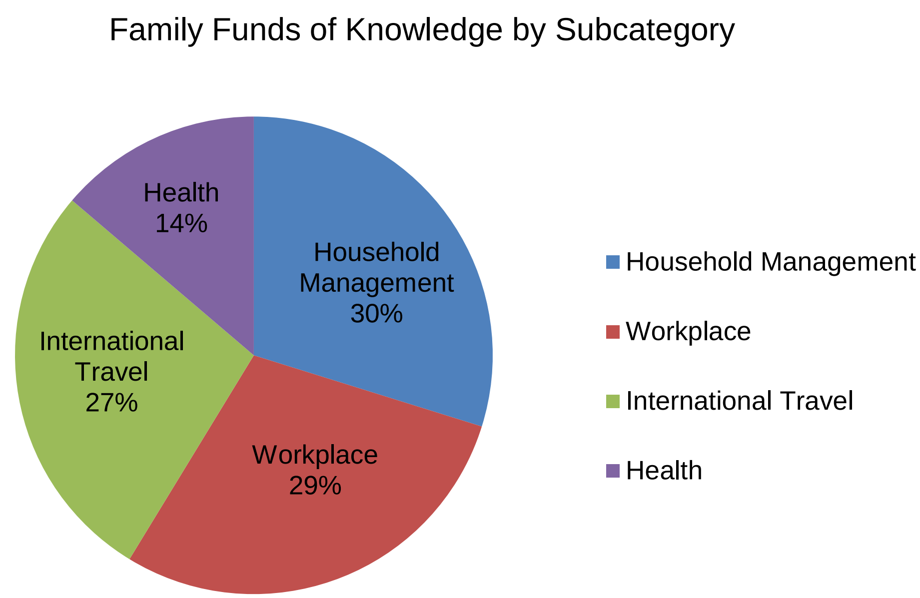

Figure 5-3. Incidence of family funds of knowledge by subcategory (*n* = 218). This pie chart was obtained from the number of instances when participants mentioned family funds of knowledge.

of knowledge. The examples described in this section are representative of patterns that were consistent throughout whole data set. The primary finding was that participants had a wide and diverse array of family funds of knowledge. In addition, I have included a description of the different engineering codes embedded in these funds of knowledge. Although these family funds of knowledge were different among participants, there were specific similarities among them such as learning how to use tools, considering economic constraints, acquiring bodies of knowledge from generational practices and activities, and an important emphasis on the well-being of individuals.

Workplace. Workplace funds of knowledge were defined as the bodies of knowledge, skills, and practices gained through the adolescents' or their relatives' employment. Moll et al. (1992) emphasized the "labor history of the families" in order to understand the bodies of knowledge, skills, and practices of the household (p. 133). Funds of knowledge can derive from the work of the parents in and outside the home (Moje et al., 2004). However, since most of the participants had held jobs during or before the study, the adolescents' workplace was also considered a source of funds of knowledge.

An analysis of the data revealed that many of the participants shared some of the same experiences related to knowledge, skills, and practices obtained from their jobs or the jobs of their parents. For example, some of the participants had learned some kind of skill related to cooking procedures because they held jobs in the food service industry or their families owned restaurants. Different focus topics were related to the food service industry as some of the participants had experiences working in this area. Carmen indicated during an interview that different skills and bodies of knowledge were gained at her job in a local restaurant:

> I learned how to cook food. How to communicate well with people. You know, before that I didn't really communicate a lot with people. I didn't really put myself out there…I learned how to be patient too because some of the customers are just really slow and you have to be patient with them.

In this quotation, Carmen indicated that learning to be patient and communicating were skills that helped her perform better as an employee at the restaurant. Her workplace experiences were related to engineering practices and dispositions as well. For example, Carmen learned about the importance of working together and communicating. Carmen's excerpt matched my description of the code *teamwork*. This code, clustered under the codes related to bodies of knowledge, dispositions, and habits of mind relevant to engineering, was described as communication with others to accomplish a common goal as a team and the division of roles in order to efficiently complete a job. According to Moore et al. (2014), one of the key components of the framework for quality K-12 engineering education is teamwork. As a contributing member of a team, Carmen had developed the skills necessary to be a contributing team member and achieve goals with others.

Carmen continued her conversation describing the workplace and how employees make burritos and take orders from customers. Carmen explained during the interview the step-by-step process of how customers came into the restaurant, asked for their food, and the process that followed until she received each customer at the cashier:

> So the beginning part is, like, you tell [the employees] what you want, like a burrito. So [the employee] gets the tortilla, and then the next [employee] will [ask], "What kind of beans do you want and rice." So they put the beans and then the rice and then you tell them what you want so it just goes like that until the end of the line and that's when I come in.

Carmen described how employees had specific tasks at different stations, such as adding beans or rice, while asking the clients what they wanted. The practices described by Carmen were similar to how employees at an assembly line work together. In assembly lines, employees focus on one task at different stations until the final product is assembled.

Carmen explained how in order to make burritos faster, one employee "gets the tortilla" then the next employee puts the rice and beans, and so on until the burrito is made. She had an understanding of how an assembly line works and the importance of a system that creates a product efficiently. She described how every employee is responsible for one task to “make the burritos faster.” Moore et al. (2014) have argued that students must learn about engineering processes that include step-by-step procedures involving specific tasks. In this case, the step-by-step procedure described by Carmen demonstrated that she understood the need for efficiency in producing a final product. For this reason, Carmen’s experiences at the workplace were coded as knowledge of *production and processing*.

The bodies of knowledge and skills described by Carmen were also similar to other participants that described cooking procedures and indicated how changing the step-by-step process could affect the final product. Participants had acquired knowledge and skills from cooking practices at the workplace and learned the importance of following procedures in a sequenced fashion. This type of sequential processes necessary to create a product is one aspect of the engineering-related code *production and processing*. The workplace funds of knowledge observed were also consistent with the work of those who argued that workplace-based funds of knowledge, including cooking procedures, could be used to “integrate everyday and scientific conceptions of particular phenomena” (Moje et al., 2004, p. 53). Similarly, funds of knowledge obtained from the workplace included a basic knowledge of production and processing, which could be used as a starting point to discuss efficiency and other engineering-related practices in K-12 classrooms.

Other examples of family funds of knowledge related to the workplace included bodies of knowledge, skills, and practices learned from parents or relatives. One common focus topic across participants was construction. For example, Clarisa’s dad worked in construction and she helped him build a garage and a gazebo. She mentioned during an interview that she just "watches and learns" from her father but also helped in the process of building:

> My dad works in construction, so I help a lot with building. We built a gazebo in our backyard. And then we built a shed. So I've helped with all that. And we built a barn and stuff. So I helped with that.

By engaging in construction activities at home, Clarisa became a significant contributor to the household functioning (Moll et al., 1992), and she acquired bodies of knowledge and skills from her dad's work-related activities. She was an active participant by helping her dad build the gazebo, the shed, and the barn. In other interviews, she also described how she helped her father build roofs.

Later during the interview, Clarisa talked about the different materials they used to build the gazebo and tools used to take measurements (e.g., measuring tape) and for leveling. She also described how material selection for construction is different depending on the environmental conditions. For example, she compared building a structure in Mexico City and in Utah. She mentioned that in Mexico homes are built with concrete but in Utah "most of [the structure] is like plywood and more wood." Clarisa said, "The humidity over there would rot the wood and so that is why they use brick."

Her descriptions indicated that she learned how to use different tools, such as a measuring tape and a leveling instrument. This excerpt was coded as *use of tools* because Clarisa explained how tools were used to construct the gazebo. Moore et al. (2014) argued that it is important for K-12 students to become familiar and proficient with the use of different tools such as hammers, rulers, or calipers. Clarisa became familiar with the use of different tools and gained skills that helped her make use of such tools to generate a product.

I also coded Clarisa's description with the engineering code *evaluate solutions* based on how she evaluated construction based on different contextualizing factors such as the weather of the region. In this quote, she evaluated whether a material could withstand humidity. She evaluated a solution component, the selection of plywood or bricks, based on environmental conditions. Evaluation, one of the engineering design activities, involves comparing and contrasting possible solutions for a problem based on particular dimensions (Atman et al., 2007). Clarisa demonstrated that she had acquired a set of skills that helped her evaluate different elements in a design. She observed how construction was done in another country and the differences that existed between two different methods. She compared and contrasted how different materials are affected by different environmental factors. Clarisa had a clear understanding that factors such as humidity affect how construction is approached in different parts of the world. Her workplace funds of knowledge had also a transnational quality (Moje et al., 2004), and her reasoning comprised not only environmental observations but also the selection of materials to create a long-lasting structure. Experiencing different worldviews allowed Clarisa to think about how different conditions and factors affect the outcome of a solution.

Other participants were also involved in transnational movements, which likewise helped them to select materials according to environmental or societal factors, and their influence on how different people approach problems. The participants in this study had workplace experiences in different countries that helped them to evaluate solutions depending on different contextual criteria. For instance, they described how population density leads to particular architectural features or how local weather influences the materials that people choose for roofs in different parts of the world.

International travel. This code was defined as the bodies of knowledge, skills, and practices derived from living in another country and/or traveling to another country. Moje et al. (2004) argued that funds of knowledge do not occur only in local settings but also transcend local boundaries. The adolescents engaged in practices and activities that had global relevance because they were based on perspectives from different areas of the world. Participants incorporated knowledge of different issues at the local and global level to their designs. This global knowledge was aligned with Moore and colleagues' (2014) assertion that K-12 students should understand the impact of engineering "solutions in a global, economic, environmental, and societal context" (p. 6). Participants frequently paid attention to how processes and structures differed around the world, and they constantly compared and contrasted solutions or approaches to problems. The participants also showed their commitment to the well-being of vulnerable populations not only locally but also globally, and they considered the economic impacts of the solutions they generated for their community-based engineering design problems.

For example, Paula lived in Honduras and immigrated to the United States when she was eight years old but constantly traveled back to her home country. She talked about differences between the urban and rural settings in Honduras and compared them to life in the United States. During one of the group discussions, Paula explained the devastation created by Hurricane Mitch and the problems that evolved after the disaster.

In fact, Paula's experiences influenced the selection of the team's community-based engineering design problem.

Paula was very interested in creating a solution that would address the problems she observed in her home country. Paula focused on the poor regions of Honduras because that is where she noticed most of the problems existed, and the devastation from Hurricane Mitch "created limited access to water." She also compared and contrasted Hondurans' access to water according to their socioeconomic status and geographic location. She indicated during an interview:

> En Honduras si una persona tiene bastante dinero manda hacer su propio pozo. (In Honduras if a person has enough money, he/she can make his/her own well). Because in the capital water is kind of easy to access but it's not quality water. They might have more water but they don't necessarily use it, they don't use that water to drink.

Paula emphasized how people with low economic resources had little or no access to water. According to her, families that could afford to make their own well had more accessibility to clean water. Hondurans who lived in the capital also had access to water, although it was not necessarily potable. "Rich people" in urban areas could afford to pay for water at a potable water distribution center owned by the government.

Paula also mentioned that poor people in rural Honduras did not have access to potable water. She talked about the economic impact that creating a water catchment system that was not affordable would have on the rural population. She said, "[In Honduras] even fifty dollars is a lot of money, I think that is one of the big things, that they may not have enough resources to do that." Paula also mentioned that the problem of water access had other interconnected factors and creating a solution could be complicated. The poor regions of Honduras could only access water from rivers or other streams that were, for the most part, contaminated. Paula said, “Hurricane Mitch destroyed a lot of pipelines where water runs, so water is not accessible by a lot of people and the majority of water that does come is contaminated because the pipelines are broken.”

An additional problem was the spread of diseases like malaria and dengue from the consumption of contaminated water. Paula indicated that mosquitoes near open bodies of water carry the virus. People got infected because their only access to water was through these open bodies of water and they could be exposed to the virus through the contact with mosquitoes. Later on, Paula mentioned during group discussions that one of the main criteria for the creation of the water catchment system should be to prevent “harboring mosquitoes.”

Based on Paula’s *international travel* experiences, Paula and her team members identified a problem in the community. This excerpt was coded as *problem definition* because Paula’s statements helped the participants generate the criteria and constraints that they would not have known if they had not visited the region. Atman et al. (2007) argued that problem definition was one of the design stages where engineers define the criteria, constraints, and requirements necessary to address a problem. The participants identified different constraints and criteria for the problem such as the limited access to water, the socioeconomic status of the population, and the spread of dengue and malaria from contaminated water consumption. Paula’s descriptions “brought about an awareness of realistic problems that exist in today's ever changing global economy" (Moore et al., 2014, p. 6).

In addition, Paula showed a commitment to help a vulnerable population (e.g., poor families in rural Honduras) and described the impact of economic factors on those populations. Because of that, I also used the code *ethical considerations and empathy* to describe these excerpts. Creating an affordable water catchment system was the focus of the project. Economic and social issues were highlighted by the participants, thus showing their interest in ethical considerations and the well-being of vulnerable populations. Ethics was identified by Moore et al. (2014) as an important characteristic of the engineering profession. According to Moore and colleagues, students should be exposed to ethical considerations as they learn to address issues in a responsible manner and consider the resources of the clients.

Most of the participants described different socioeconomic conditions in different countries. Their awareness of people's lack of resources demonstrated their ethical considerations and empathy toward vulnerable populations. For example, another participant from a different group also mentioned the differences between affluent and poor areas in El Salvador. Katy indicated that people in El Salvador have access to quality services only if they have certain economic status or live close to big cities. Katy indicated during an interview:

> So in the capital there are roads, and flowers everywhere, and there is a fence. They have a lot of buildings, and their mall is bigger than [a U.S.] mall. There are nice cars, and everything is luxurious. Their parks have everything that you could possibly imagine, their water parks are nice. And where we have our house, it's

> like the road is barely made out of cement because it used to be just mud, there is no garden…For us to drink water, my mom has to cook with like, say, Culligan water from here. So every Tuesday or Wednesday a truck comes around and you pay for water…and you have that for a week. And if you use it all before they come back, then you have to drive to a store to get another one.

Katy understood from her life in El Salvador that resources were distributed unevenly based on economic status. She compared and contrasted life in different parts of El Salvador in a social and economic context. She mentioned the problem of access to water in El Salvador and how expensive it could be to get water for poor people. This example demonstrates that Katy's life in El Salvador fostered a commitment to the well-being of vulnerable populations, such as poor people who lived in regions where clean drinking water was hard to find.

She demonstrated this commitment to vulnerable populations throughout the project as well. During the group sessions, she focused on the well-being of individuals with physical disabilities, also a vulnerable population, and emphasized the importance of making their solution accessible to people who were poor. Thus, she had developed an awareness of economic impacts and their consequences. This commitment to vulnerable populations also helped her in the problem scoping stage of the community-based engineering design problem because she used that knowledge to define the audience for her product (e.g., poor people with physical disabilities).

In addition to fostering empathy, Katy's transnational experiences also gave her experience with *evaluating solutions* according to local regional criteria. When asked to describe her home in El Salvador during an interview, Katy made observations similar to those made by Clarisa. Katy described her house in El Salvador as “very different” from her house in the United States. She said, “It’s a two story house, and over there the houses are made of cement. There’s no drywall, there’s no wood. It’s all cement and brick.” She went on to highlight the use of different materials due to the humidity in the region. Katy also indicated that cement was an available resource in the region as opposed to the access to drywall, which could be expensive. Like Clarisa, Katy evaluated construction materials based on contextualizing factors such as the humidity of the region and access to materials.

Katy experienced different worldviews that allowed her to think about interconnected variables and how to solve a problem taking those factors into consideration. Katy demonstrated her ability to discern how changes in one variable (e.g., humidity) could affect material selection or the final product, as described by the code *evaluate solutions*. Thinking about different variables and how they are interconnected is important for students to understand how solutions may have an impact at local and global levels. As indicated by Moore et al. (2014), it is important for students to incorporate knowledge from different global perspectives to their engineering solutions. Katy’s descriptions indicated that her international travel funds of knowledge helped her to develop bodies of knowledge, dispositions, and habits of mind consistent with engineering and engineering thinking.

These examples are representative of what other participants discussed regarding international travel. For instance, several other participants held experiences with poverty in other countries, contributing to their sense of commitment to under-served populations around the world. Most importantly, the funds of knowledge brought a global perspective to the problem, indicating that diverse students can bring needed global perspectives and diversity to the engineering classroom (Moje et al., 2004). The participants in this study were also aware that solutions to problems had to address local economic and social aspects in order to be effective.

Health. A theme that emerged from the data analysis related to different concerns regarding the well-being and health of individuals. This code was developed to integrate the data patterns describing the bodies of knowledge, skills, and practices related to improving, maintaining, managing, or repairing physical or mental health. The data showed different patterns where the participants described their experiences with health-related issues and their perspective on how to help those who were in distress. Some of the participants' narratives were based in cultural and social practices that have been transferred from generation to generation (Gonzalez et al., 2005; Moll et al., 1992). The data patterns align with Moll and colleagues' (1992) description of funds of knowledge used by students to explain the use of folk medicine, herbal knowledge, first aid procedures, and the use of home remedies to improve health. The representative examples listed below reflect how the participants used funds of knowledge related to health to address their community-based engineering design problem.

The participants had experiences with producing solutions to health problems while working within tight economic constraints. Sofia shared during a group discussion some of her experiences using "home remedies" with her grandmother and mother. She mentioned that even though it is something she feels skeptical about, "it is from generations" and that "it is something [she] will use." Sofia emphasized that home remedies not only improved health, but also helped the family economy. It was a practice that had been carried out through generations and used to treat sickness during times of economic hardship. She went on to describe one interaction she had with her grandmother:

> Like my grandma sometimes, like if I have a fever, she would give me a tea…She would just put in different, like stuff, like little seeds and stuff, and then she would just give it to me. I asked her, “Why not just go get a medicine at – like a medicine store or pharmacy?” And she's like, “No, because this works and my family has had it for generations and you can use it.”

Sofia’s experiences indicated how Latino families have relied on the medicinal properties of different herbs to promote health and well-being. Her grandmother’s solution resonates with another topic most participants talked about – the importance of obtaining or creating products that were cost-effective or finding cost-effective options. Sofia’s teammates repeatedly emphasized cost as a significant constraint that needed to be considered in the design process.

According to the members of the team, people who were sick probably did not have a lot of money because being sick involved spending large amounts of money on medical bills. When the participants started to define the constraints of the community-based engineering design problem, economic limitations of the client were mentioned repeatedly. They had developed an awareness of economic constraints for many clients. The participants wanted to provide a device that the client could afford. One characteristic of *problem definition* was to identify constraints, and they constantly tried to use affordable materials that would result in an inexpensive product.

Sofia expressed the importance of *ethical considerations and empathy* in order to improve or maintain the health of vulnerable populations. The participants in this study considered people with low socioeconomic status part of vulnerable populations, and made an effort to generate solutions that could benefit them. It was clear from their conversations that one of their main interests was to make everything affordable. Their concern for making products available to people with low socioeconomic status resonates with Moore and colleagues' (2014) emphasis on the importance of incorporating ethics to the engineering education framework for K-12. They argued that teachers should encourage students to consider issues, solutions, and impacts in a social and economic context.

Sofia's experiences were also shared by other adolescents such as Felicia, Alejandra, Paula, Clarisa, Andrea, and Sandra who also mentioned how "home remedies" were a clear alternative to costly medications. These participants commented on their reliability because these alternatives had produced positive results throughout generations. Sandra, for example, explained during a group discussion how her mother, even though she was a nurse practitioner in Guatemala, also relied on "white vinegar and apple vinegar" to stop nose bleeding. She mentioned that those alternatives were used to prevent spending money on medication that could be easily made at home.

Another example of the knowledge related to improving, maintaining, or managing physical health came from a narrative by Tomas during a group meeting. His knowledge about Duchenne Muscular Dystrophy (DMD) was a topic of focus during the project. Most of his knowledge about the disease came from personal experience because two of his brothers suffered from this condition. He talked about how the disease is genetic but "only boys will get it." Tomas talked about different types of muscular dystrophy but reiterated that the genetic mutation is mostly exhibited in males. He understood not only the signs and symptoms of DMD but he also learned scientific concepts about the disease. Tomas described DMD as a condition where "muscles stop working so [individuals with DMD] will eventually get permanent to the wheelchair." He also indicated that the bones and muscles become fragile, thus affecting the physical abilities of the individual, such as the inability to control movements.

Because Tomas offered relevant information about DMD, these excerpts were coded as *scientific knowledge*, which was one of the identified codes related to bodies of knowledge, dispositions, and habits of mind related to engineering. Tomas understood scientific facts and principles based on a problem he observed at home. Tomas' team worked on improving a shower chair headrest for his brothers who suffered from DMD. Based on the information provided by Tomas, his team was able to identify the client's needs as well as the criteria and constraints to design the shower chair headrest. For example, based on the knowledge that DMD caused muscular degeneration in the neck, the team established that one criterion for a successful design of a headrest was that it should keep the client's head stable even when he could not hold it up himself. Tomas' experiences with muscular dystrophy provided him with a degree of scientific knowledge that he could apply to engineering design, which resonates with Moore and colleagues' (2014) assertion that it is important to apply scientific knowledge to engineering design.

The participants' experiences with physical injuries also helped them to *identify needs* and *define problems*. Their family members' injuries inspired them to want to build a device or process that could alleviate their suffering. Tomas for example knew that one of the main symptoms of DMD was progressive body deformities, fragile bones, and eventual loss of muscular strength. His brother had lost his ability to hold his neck and head upright, thus making it difficult for Tomas and his family to bathe him without hurting him. Tomas explained that although his brother used a shower chair to bathe, the shower chair was old and did not have anything to support his brother's head and neck.

Tomas mentioned that one of the reasons for this problem was that individuals who suffer from DMD "are expected to live only a few years," but his brother had lived longer than what doctors expected and was too big for his old shower chair. Tomas and his family were from a low socioeconomic status and could not afford a new shower chair. Following Tomas' explanation of the disease, Claudia pointed out:

> We could do the project for people with [Tomas' brother's] condition so it'll be for his brother…and I think if we made it just for one client, it would be a better, better quality. We'd pay more attention to all the things that would influence [Duchenne Muscular Dystrophy] instead of making it for a bunch of people.

Claudia talked about focusing on one single client (e.g., Tomas' brother) in order to design a "better quality" product according to his needs. Subsequent group discussions included investigating what were the specific physical needs of Tomas' brother. Also, because Tomas' family could not afford a new shower chair, the participants decided to improve the current shower chair and possibly design something that Tomas' family could make themselves from inexpensive materials available at local stores.

By identifying the specific needs of a single client and identifying the areas for improvement for the shower chair, the participants engaged in problem definition or problem scoping. According to Atman et al. (2007), problem scoping and information gathering involves identifying criteria, constraints, and requirements necessary to frame a problem. In accordance with this definition of problem scoping, I coded for *problem definition* when the participants engaged in discussions that framed the problem based on different constraints and the specific audience they wanted to target.

Tomas' team worked and focused on one specific client and tried to meet his specific needs. Then, they planned how to approach the problem to meet those specific needs by gathering more information about DMD, looking at the current shower chair, looking at different materials they could use, and designing a headrest for the shower chair. Moore et al. (2014) argued that students should be "able to formulate a plan of approach and should be able to identify the need" (p. 5). The adolescents participated in activities that allowed them to learn more about the problem and generate a possible solution to that problem. Tomas' knowledge of DMD provided the team with the basis for the problem definition. His experiences were extremely valuable for the team as they tried to solve the community-based engineering design problem.

In addition to helping the participants define the problem; their experiences with injuries also provided the basis for *generation of ideas* and their final *communications* of their design. During the problem definition stage, Tomas indicated that individuals affected with DMD usually do not reach adulthood. Although doctors had indicated that his brother would only live until his teenage years, his brother reached adulthood and was too big for his old shower chair. Claudia and Sandra discussed that, even though the headrest for the shower chair would be designed for Tomas' brother, they wanted to design an adjustable shower chair headrest in case other families with kids that suffered from DMD wanted to use their design. Sandra mentioned that even though the life expectancy for kids with DMD is low, some of them reach adulthood and wanted to provide a solution "add-on" to their design that could be beneficial for other kids. Claudia thought of applying a mechanism similar to those she had observed in the crutches used by some of the students with physical disabilities at her school. She said, "You know how there are these bump things that you push down and it will make it go longer? That's what we were thinking with the headrest. You could push and then pull up." Claudia had observed how crutches have a mechanism that makes them longer or shorter and used this experience to *generate ideas* for their design.

Based on this principle, Claudia suggested using something similar to the crutches to make the headrest "move down and move it up to make it shorter or taller." Sandra and Claudia later designed a headrest that included a mechanism similar to those used in crutches as shown in Figure 5-4. They used sketching to communicate their design to their team members and to a university student that helped them create a computer-aided design of their sketch. Figure 5-4 was considered a form of data that was relevant to *communication*, a code related to engineering design processes. In other words, their experiences with crutches enabled them to visualize one component of the shower chair headrest, showing that experiences with poor health contributed to their abilities to draw out their solutions.

The adolescents participated in practices similar those described by Moore et al. (2014) regarding communication related to engineering. According to Moore et al. (2014), it is important that K-12 students communicate in manners similar to those of engineering professionals such as using symbolic and pictorial representations. Sandra and Claudia used a sketch to communicate their design to their team members. It can be

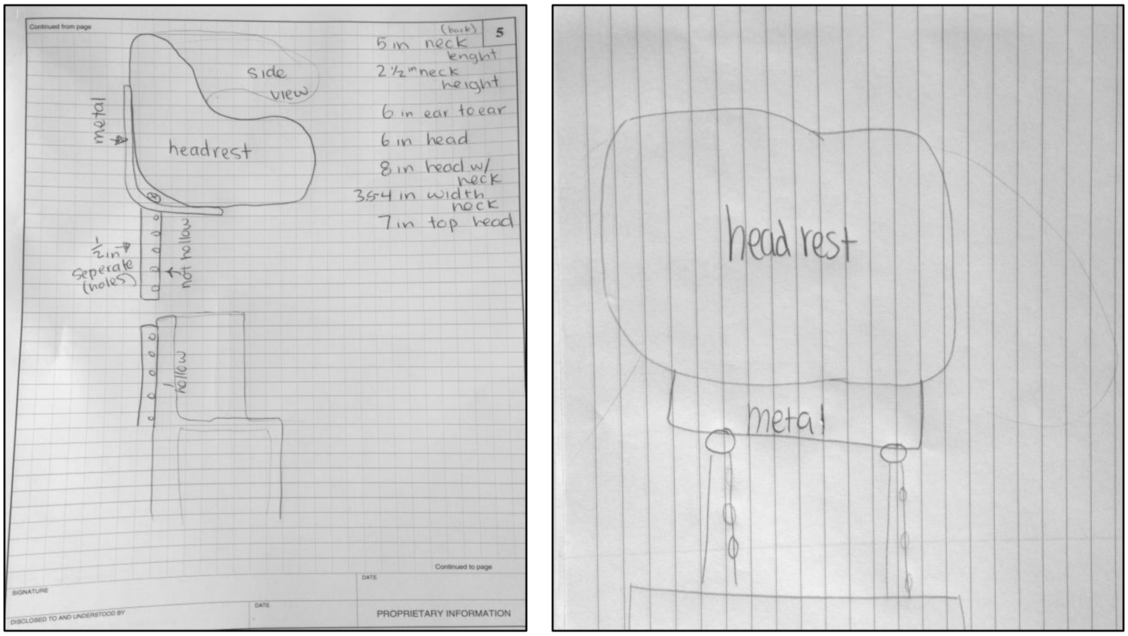

Figure 5-4. One example of participant-generated sketches. These images show how the participants engaged in sketching and used tools (i.e., measuring tape) to communicate a potential model. The images also show how adolescents addressed the needs of the client by including certain characteristics such as an adjustable mechanism.

observed in Figure 5-4 that their designs included the criteria previously identified by the team members such as an adjustable headrest using a mechanism similar to that used in crutches and support for the head and neck. The image on the left shows a "side view" of the headrest. The image on the right shows a "frontal view" of their sketch.

The sketch also includes measurements that they thought could be representative of an "average head size." Claudia used a measuring tape to measure the different dimensions they wanted to specify in their design. According to their design, they wanted to have a specific separation (0.5 inches) between the "holes" of the crutches. This design element would allow for "height and neck adjustment" according to Sandra. Also, the sketch shows an L-shaped piece of metal that would "provide support" and would be strong enough to keep the client's head from going backward. Later on, Claudia and

Sandra gave the sketches to an undergraduate student who used the drawings to create a three-dimensional model using solid modeling.

Another emerging topic from the conversations with Tomas and his team was the economic impact that serious conditions such as DMD have on the family. It is important to mention that three out of the four groups talked about how maintaining or improving health was related somehow to economic constraints. Several participants had previously worked with people with physical disabilities and learned how to take care of other people who required constant monitoring due to their condition. Sofia and Sandra had previously worked at a nursing home, and Carmen, Dulce, Felicia, and Katy had tutored students with physical disabilities. Through these experiences, the participants developed bodies of knowledge, skills, and practices not only related to maintaining, managing, or improving physical health, but they also demonstrated their commitment to the well-being of vulnerable populations and the impact of economic constraints for the individuals with physical disabilities and their families. Their commitment to under-served populations was assigned the engineering code of *ethical considerations and empathy*.

Two groups, the Wheelchair Swing Team and the Headrest Team, focused on improving or designing an artifact that could be used by individuals with physical disabilities. The Water Catchment Team focused on designing a water catchment system that could be used by families with low economic resources, which also demonstrated their commitment to populations that are often under-served. The water catchment system was designed specifically to prevent any spread of diseases like malaria or dengue due to sanitation issues, which demonstrated their awareness of community health issues such as the spread of disease. In all, the adolescents' experiences with health-related issues helped them to engage in practices that involved identifying problems, and creating solutions that could be used by vulnerable populations at home and in their communities.

Household management. Improving and maintaining living conditions was another theme that emerged from the data. All participants mentioned participating in projects that involved building, cooking, managing budgets, or childcare in and out of the home. Gonzalez et al. (2005) described these practices as being relevant to formal academic knowledge. The subcategory described as "household management" in this study includes the bodies of knowledge, skills, and practices derived from maintaining basic family functions or from constructing, managing, or improving a household, a yard, or items within them. Because some adolescents participated in some of these activities with the community as well, only instances of practices that occurred within their own homes were considered as relevant for household management.

The patterns shown in the data were similar to Gonzalez and colleagues' (2005) description of household management. For instance, all of the participants had built structures, such as garages or entire homes, requiring them to use tools and measuring techniques. As explained by Moll et al. (1992), "household management" also includes funds of knowledge required to adapt to changing social and economic situations. For example, due to the lack of money to buy new clothes, Emiliano's mother taught him to operate a sewing machine to fix or make his clothes. Emiliano's mother learned how to use the sewing machine in Mexico from a neighbor who had a boutique and would let her use the machines. Emiliano learned from observation how to repair his own pants, the function of different types of needles, and how to make the clothes last longer. During an interview he said:

> I’ve tried fixing pants but it didn’t work very well because after a while they sort of lose their shape. But it depends on what kind of needle and thread you use. If it’s too big it leaves holes and it doesn’t look very good any way. But if your thread is too fine, it’s just going to break anyway. So it just kind of depends on what kind of needle and thread and how you sew it together.

This example shows how Emiliano gained knowledge about using different needles for different sewing purposes. Emiliano talked about the choosing the right thread and needle to make the clothes last longer. He talked about how he learned how to operate the sewing machine and choose thread, needles, and fabric to make clothes more durable. According to his descriptions, fabrics also needed to be selected carefully because they each have different properties, which may affect the quality of the product.

The engineering code embedded in Emiliano’s household management funds of knowledge was *evaluating solutions*. Emiliano’s descriptions showed his ability to evaluate solutions for repairing his pants based on one or more criteria or constraints. According to Emiliano, using fine thread was sometimes not a good option for sewing because it could break easily. However, using some fabrics required the use of fine thread because using thicker thread and bigger needles could leave “holes” on the fabric, making it visually unappealing. Emiliano considered different trade-offs resulting from the selection of different types of thread, needles, or fabric used when sewing. In an attempt to make the clothes functional, Emiliano also considered different criteria for his approach to repairing his pants, including material selection and sewing techniques.

Emiliano applied the funds of knowledge he had gained from household management to his team's community-based engineering design problem. During the group discussions with his team, Emiliano talked about how the construction of the shoe they were designing needed to take into consideration different factors he learned from sewing. For instance, while describing shoe construction, he referred to the size of needles, "seaming two different types of fabric together," the type of thread to be used, and the material to be considered. His teammates wanted to include three different layers to their shoe. The first layer consisted of a water repellant fabric. The second layer was wool in order to keep the feet warm during the winter and make the shoe comfortable. They also considered a third thermal-reflective later in order to keep the temperature inside the shoe warm.

Emilio explained that, from his experience with sewing and using different fabrics, he questioned the effectiveness of using wool as one of the fabric choices. He said, "I don't know, the wool would be kind of fluffy but I'm not sure how it would exactly stay up but yeah I'm not picturing how it would stay up, like the shape." Working with different fabrics helped Emilio understand how fabrics may behave and what they can be used for. He indicated that even though wool could be a good choice for comfort, he doubted whether this kind of material would "stay up" and provide shape to the shoe. He later talked about how difficult it could be to work with "fluffy materials" because the needles may destroy the fabric. Moreover, he explained during the group discussion why it could be difficult to work with three different fabrics and make the shoe look professional:

> Okay that's another thing we would have to look at. Like how to actually keep the shoe into shape and then you can sew around that. That would be the next step. Because each layer would actually be kind of combining with each other so it would actually hide that crease because it's not just one big fabric thing – it is multiple pieces. So it's kind of like folding them and sewing it together so they don't show.

Emilio related his experience with making clothes to the construction of the shoe. He explained how different materials needed to be selected in order to keep the shape of the shoe and make it look aesthetically pleasing. He explained that, even though he had never made a shoe, his team members needed to think about how to put all pieces of fabric together, prevent the water from going into the shoe, keep the shape of the shoe, and prevent the seam from showing in order to make it look appealing to the consumer.

This excerpt was coded also as *production and processing* because Emilio considered knowledge of materials and production as his group sought to design a product. Emilio's sewing experience helped his team to search for alternative solutions and generate ideas for their product. Emiliano evaluated materials, not just based on whether they could be effective in a final product, but also in regards to whether the materials would make the production process easier or harder. Emiliano argued that, although wool would be a good option, sewing the three pieces of fabric together could destroy the middle fabric layer. In addition, Emiliano emphasized that making a shoe with three different layers of fabric could be a difficult task because it required a more difficult production process to construct the shoe.

Sofia, a participant from another group, talked about similar experiences with sewing. Sofia talked about how her grandmother and her mother taught her how to make or fix clothes by sewing. She indicated during an interview that sewing was a practice passed from generation to generation:

> In Mexico it's a tradition…The first time [my grandma] showed me how to sew when I ripped my pants. She showed me how to sew it up back in and, you know, that's where I mainly learned how to sew from my grandma…I have pretty much sewn my couch. My sister started jumping on it. My sister kept jumping on my couch and finally one day the edge ripped. So what I did was just start grabbing the two pieces and sewed it all around…I have sewn my couch, I have sewn my blankets, my sister's clothes – I have sewn pretty much anything that is easy for me.

Sofia used her bodies of knowledge, skills, and practices derived from sewing to fix or make different items around her household. Later on, Sofia used her sewing skills to help her group conceptualize and construct the shower chair headrest prototype, as shown in Figure 5-5.

Sofia came up with the idea of creating a model similar to a travel neck pillow during a group discussion. She and her teammates went to a local arts and crafts store and investigated what kind of material would be resistant to water because the material to be used for the headrest would be exposed to water constantly. They found a type of fabric with vinyl on the surface that could be used for the headrest. The team members decided to take the material home to test it and make sure that it was water resistant because they wanted the material to last for a long time.

Figure 5-5. An example of a participant-generated artifact. Sofia applied her sewing skills, considered a fund of knowledge related to household management, to create a prototype that would eventually evolve into a full-scale design.

Sofia took the initiative to create a physical model (Figure 5-5) using the information gathered from her team and her sewing skills. Sofia explained during a group discussion that she decided to make the pillow and test it afterward. She said:

> I didn’t know how to make it a headrest so I made a pillow…I just cut it out and started sewing the edges in…I first looked at the fabric. It was long and it was uneven. So I cut it into two pieces and put them together and just started cutting it out the same length on both sides. I got the idea to turn it into a pillow. The reason I sewed it inside out was because most of the things I have ever done and sewn are inside out, and the reason for that is it stays and is more flexible and it stays longer than if you just sew it.

Sofia used her sewing skills to create the pillow based on practices she learned at home. She clearly indicated that that she made her prototype following steps she had previously used to make other items. She mentioned that she cut the pieces of vinyl the same length and sew them together inside out because that is exactly how she had done it before. She also said that one of the reasons for constructing the pillow that way was because it “stays longer” if it was sewn inside out. In other words, according to Sofia, the product would last longer if the seams were on the inside of the pillow rather than on the outside.

I coded this excerpt as *production and processing* because by sewing Sofia knew that if the seams were sewn on the outside the product would not last as long or look its best as if the seams were sewn on the inside. In addition, Sofia explained how she constructed the pillow through a step-by-step process. She explained how she cut two square pieces of vinyl identical in size. Then she sewed the two square pieces of vinyl together along three of the edges. After she sewed along those three edges, Sofia pulled the vinyl inside-out, keeping the seams on the inside of the “pillow.” Sofia then filled the pillow with cotton and sewed the fourth side of the vinyl on the outside completing the production of her pillow. Sofia then tested her prototype by “punching it” and noticed that the one seam that was not sewn on the inside let “air escape.” She indicated that, because air could escape from the side where the seams where on the outside, the way the headrest was put together mattered in the sense that it influenced the effectiveness of the final design. Sofia emphasized that if the headrest was not made correctly then water could get inside the headrest, making it “smelly” and decreasing its durability.

In addition to coding Sofia’s sewing skills as relevant to the engineering code of *production and processing*, I also coded this data excerpt as *modeling* because Sofia created a prototype of a pillow that was later tested and used to evaluate solutions. Atman et al. (2007) listed modeling as a particular design activity that applies to initial solutions and could affect the final design. Sofia’s model was important for the project it gave her teammates a visual of what the headrest could look like. This model was also important because it enabled Sofia and Sandra to test which method of construction (e.g., sewing the seams on the outside or the inside) would work best. After Sofia and Sandra tested the materials, they confirmed that the vinyl was an appropriate material for the shower chair headrest. Thus, Sofia’s prototype influenced the final design and subsequent solution evaluations.

The participants’ experiences with household management also taught them how to work under economic constraints, a skill relevant to engineering. Felicia gave a very interesting example of learning how to be resourceful and adapting to economic constraints. Her mother operated a restaurant in Mexico, but she did not have the resources to buy a new stove. To solve this problem, her family made a cooktop by repurposing an antique washing machine. Felicia described the washing machine as a “chaca-chaca,” as it is commonly known in Mexico for the sound it makes during the washing cycle. The washing machine was a simple top-loading roller washing machine with a mangle attached, commonly known as a wringer washer. Felicia and her family disassembled the washing machine and used the tub as the skeleton for the cooktop. They then covered the tub of the washing machine with mud. Felicia mentioned that using mud for different purposes was a “common” practice in Mexico because mud was a material readily available around the area.

Felicia also explained during an individual interview how the old washing machine was used to give structure to the cooktop but it was covered with the “mud” to withstand high temperatures:

> We used the top part of the *lavadora* (washing machine). The bottom we didn't need, so we covered the rest out with mud – I guess so when it burned it wouldn't melt the metal, and so we had all mud and the inside was mud. That's how you make everything, with mud. You make a lot and it's – I think the fire it wouldn't melt [the metal], like it would be too strong for the *lavadora* (washing machine)… So they put mud and the mud can handle the heat.

Felicia observed that certain materials can be used as a protective layer for other materials, while strong materials can be used to provide a solid structure. Felicia noticed that the *lavadora* was disassembled and the motor, what she called the inside, was not necessary. Only the tub was needed and they covered this cylindrical structure with mud on the outside and inside. During our conversation, Felicia mentioned that a small rectangular cut was made on the cylindrical tub so that they could put *leña* (firewood) inside the tub and use it like a cooktop. A sketch representing Felicia's description is shown in Figure 5-6.

From her experiences with creating and maintaining the cooktop, Felicia learned that certain materials that are easy to access and affordable can be used to create other products. Felicia lived in a mountainous region of Mexico where, since pre-Columbian times, the population has relied on the use of *barro*, or mud, to make bowls, plates, cups, vases, heaters, and sculptures. This type of material was described by Felicia during her interview when Felicia indicated that it "solidifies" very quickly. Felicia explained how *barro* is used in everyday life in Mexico. She also mentioned that after the main structure was made, a *comal*, a type of cookware made out of cast iron, was placed on top of the structure to prepare food.

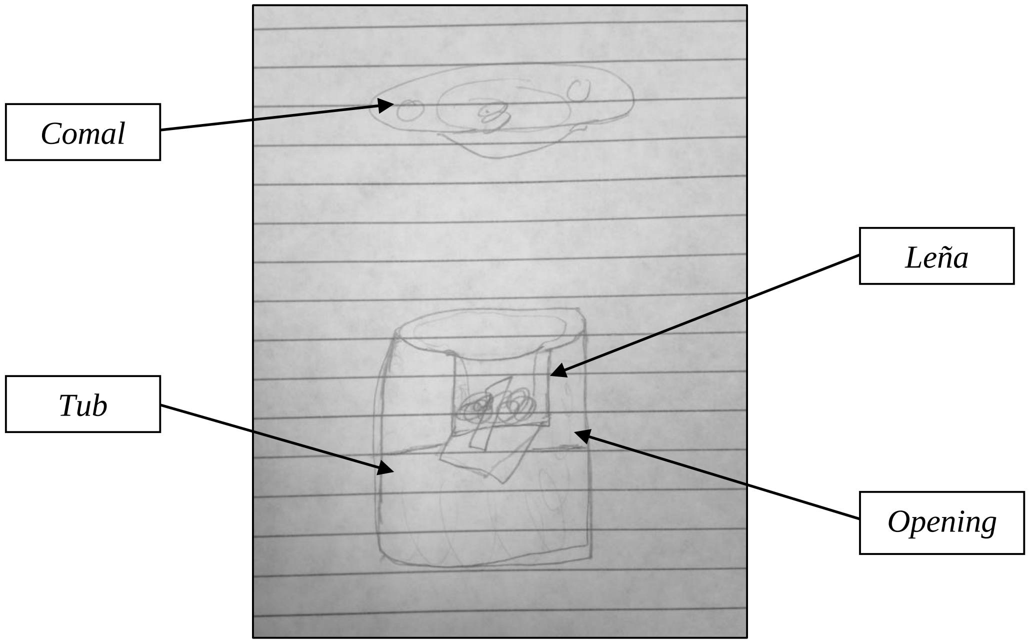

Figure 5-6. Participant-generated sketch of a solution element. The image illustrates the description made by Felicia regarding the structure of the cooktop she helped to make in Mexico. It can be observed that there is an opening on the bottom of the cylindrical tub where *leña* was introduced to create fire and use this whole structure as a cooktop.

As demonstrated by this example, Felicia used her funds of knowledge to engage in practices that were relevant to engineering. The engineering codes embedded in her funds of knowledge included *production and processing*. Felicia performed an activity that required her to look at different materials and processes to generate a product. She applied knowledge of materials, such as the knowledge of the properties of “mud,” in the creation of a design. She also considered how to create a product that was cost-effective by using local and readily available materials, but at the same time she sought to maximize efficiency in the sense that her family wanted to use the cooktop for her restaurant and increase their profits. Working within constraints, such as the availability of materials, was considered by Felicia’s family because they hoped to minimize costs associated with the construction of the artifact. Thus, the objective of this activity was to maximize profits gained from a relatively inexpensive design. She also enacted sequential processes in order to build the artifact – first by disassembling the washing machine, making an opening to the bottom of the cylinder, then covering the tub with mud, and finally placing the *comal* on top of the mud-covered tub to use it as a cooktop.

Summary of family funds of knowledge. The narratives described here are just a few examples of how the participants used their funds of knowledge to engage in engineering-related practices. The participants possessed many family funds of knowledge that were relevant to engineering, such as *production and processing*, *evaluating solutions*, *defining problems*, *identifying criteria and constraints*, *modeling*, the *use of tools*, and *ethical considerations and empathy*. One common pattern observed in the data was the consideration of economic constraints in order to provide cost-efficient products and solutions and help vulnerable populations. Culturally, within underrepresented populations, there was often a sense of responsibility and desire to contribute positively to their communities (Moje et al., 2004).

Family funds of knowledge were gained through different activities and practices at home, work, or during transnational movements. These life experiences showed how the participants gained knowledge and skills through observations, learning from others, and personal discovery. More importantly, participants made connections between their life experiences and the problems they observed in the community, and used these experiences to provide alternative solutions to those problems they observed.

Recreational Funds of Knowledge

The codes related to recreational funds of knowledge were organized using a similar method employed to categorize the previous category and subcategories. Three different subcategories emerged from the data analysis: (a) digital technologies, (b) popular cultures, and (c) sports. It is important to highlight that, although popular cultural funds of knowledge were previously described by Moje et al. (2004), the data gathered from this study suggested that sports also comprise a valuable source of bodies of knowledge, skills, and practices. The purpose of this section is to present the funds of knowledge derived from different forms of popular culture, entertainment, or interaction with technology. The data suggested that participants relied on recreational funds of knowledge to generate ideas or alternative solutions for their community-based engineering design problem. Moje et al. (2004) argued that popular funds of knowledge may not seem to relate to science learning directly, but they may be used to promote scientific understanding. Similarly, the data collected from this study indicated that recreational funds of knowledge provided resources for the participants' engineering project and how they approached their solutions.

As shown in Table 5-3, all participants mentioned recreational funds of knowledge (n = 93) during the group discussions or interviews. Figure 5-7 illustrates that the participants tended to draw from digital technologies to solve their engineering problems, but they also drew from their knowledge of sports and popular culture to a lesser extent. The data showed that the participants' recreational funds of knowledge were very diverse. Some of the examples included learning about science and mathematics from iPad applications, soccer, skiing, and online platforms. The availability and accessibility of resources from the internet was one of the topics generally discussed by the participants. The internet became one of the preferred sources of information for many of the adolescents.

Table 5-3

Number of Instances When Each Participant Mentioned Recreational Funds of Knowledge (n = 93)

Participant name	Number instances
Samuel	15
Patricio	12
Clarisa	10
Emiliano	8
Paula	7
Sandra	6
Tomas	6
Claudia	5
Dulce	5
Felicia	5
Sofia	4
Alejandra	3
Katy	3
Carmen	2
Andrea	2

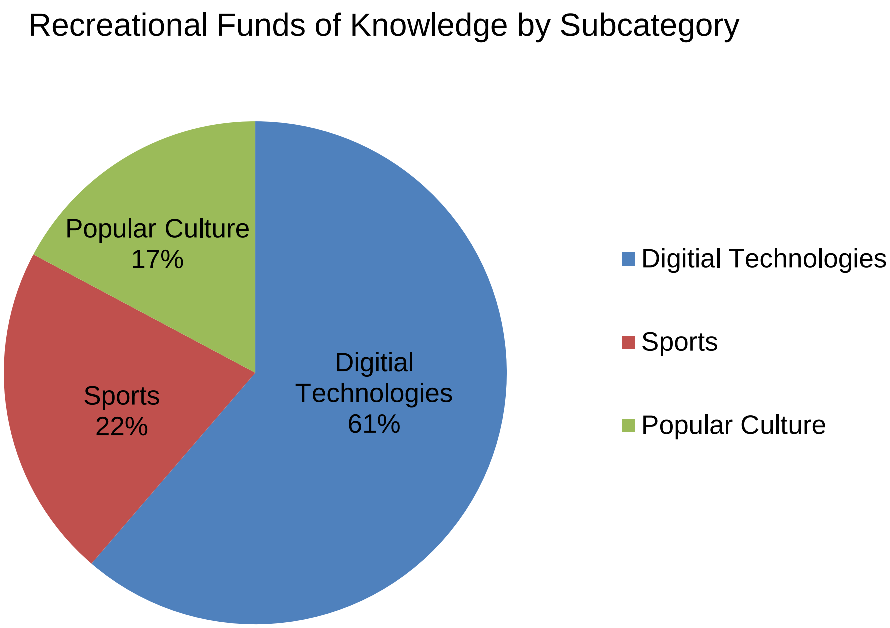

Figure 5-7. Incidence of recreational funds of knowledge by subcategory (*n* = 93). This pie chart was obtained from the number of instances when participants mentioned recreational funds of knowledge.

Described in the following sections are the three subcategories within the recreational funds of knowledge category. In addition, each subcategory contains the engineering-related codes embedded in the participants' bodies of knowledge, skills, and practices relevant to recreational funds of knowledge.

Digital technologies. This subcategory was defined as the bodies of knowledge, skills, and practices derived from interacting with a number of technologies, such as social media, applets, and video games. Digital technologies encompass digitized information that can be represented as words and/or images through different devices. According to Marsh et al. (2005), "children are immersed in practices relating to popular culture, media, and new technologies" from an early age (p. 5). As expressed in this statement, the Latino participants in this study developed a wide range of bodies of knowledge, skills, and practices related to digital technologies.

In addition, digital technologies were rated as one of the most useful sources of information during the exit interviews with the participants. Google, for example, was mentioned several times as a good and accessible source of information because it provided not just written but also visual information that helped the adolescents make decisions, generate alternative solutions, define the problem, and gather information regarding materials or costs among others.

Felicia and Dulce, for example, talked about how significant the internet became when trying to *generate ideas* related to a swing for wheelchairs. Dulce mentioned during an interview that she “had never seen one” and the internet helped her understand what a swing for wheelchairs may look like. When asked about what was the most important source of information for her project, she replied:

> The internet. Well, I probably found other wheelchair swings things that were made before in the past, and then at school we found, like, measurements of [a regular swing] or how much a wheelchair weighs. Probably the visual. Because that’s how we got our idea of how it was going to look. That’s where it all started pretty much – looking at it.

Dulce explained that without “the visual” element the group probably would not have been able to continue working on the project. By looking at several pictures of a “swing for people with disabilities” (the words used in the Google search engine), the adolescents got an idea of what this type of swings looked like. Dulce emphasized the importance of the internet and considered it as a source of information necessary to *generate ideas* on how to design an improved version the swing.

Felicia agreed with Dulce and said during an interview, “Yeah, I’m going to say the internet too [was the most important source of information] because we didn’t really know what a disability swing was like until we looked it up and that’s what gave us the idea.” Felicia also did not know how to approach the problem because she had never seen a swing for people that used wheelchairs. However, the interaction with digital technologies provided a space for learning more about the topic of interest.

This example also indicated that engineering-related practices were often embedded in digital funds of knowledge. One of the prerequisites for understanding engineering design and providing a solution to a problem, according to Moore et al. (2014), is to research the problem and identify constraints. In order to research the problem, Felicia and Dulce looked for information on the internet with the intention of determining how to improve previous designs. After they researched different designs and looked at different images, they concluded that those designs could be improved. Carmen, one of their team members, said during a group discussion, “We came up with a wheelchair swing from Google too – we saw the pictures there and we thought we could improve it more.” Although they had never seen a “wheelchair swing” before, gathering information from the internet allowed them to see different constraints or areas of improvement, but also allowed them to “formulate a plan of approach” (Moore et al., 2014, p. 5).

Like Moore et al. (2014), Atman et al. (2007) emphasized that problem scoping and information gathering are very important steps in engineering design. After the participants had the opportunity to see different images of "wheelchair swings," they identified areas of improvement such as including ramps to make them more accessible and give the client a sense of "independence," according to Carmen. Katy indicated during a group discussion that adding the two ramps to an existing design they found online would allow the person in a wheelchair to "get into the swing from both sides." Felicia explained during an interview that the information gathered helped them make the decision to "put ramps" and "make it safer so that [the wheelchair] doesn't wheel off." Overall, digital technologies provided a source of knowledge in the *information gathering* stage of the engineering design process. The participants looked for information on the internet and indicated specific areas for improvement. For instance, they looked for information related to costs, measurements, materials, and designs among other types of information. Using the information gathered from the internet, they also *generated ideas* regarding potential solutions for the existing designs such as adding "ramps" and making the swing "safer."

In addition, digital technologies became an important engineering tool to help the participants communicate their ideas in an effective manner. Felicia's group reached out to a university student to help them generate the design of the swing with solid modeling software. They provided verbal feedback to him as he used the software to modify or create different features of the design. Although the participants were not proficient in solid modeling software, they engaged in a practice that involved the use of digital technologies. During the designing process, Felicia and her teammates engaged in *communication* related to engineering by "communicating their technical ideas in common knowledge" to create a final product (Moore et al., 2014, p. 6). This team communicated their final design to the head of their town's park and recreation division. They made a presentation where they explained how they worked on the project and showed an image of their design. According to Moore et al. (2014), it is important for students to communicate their ideas through multiple representations and forms including reports, schematics, and visuals. The experiences with digital technologies enabled them to communicate their design (Figure 5-8) to a client, which is an important part of the engineering design process (Atman et al., 2007).

Popular culture. This subcategory represents one of the funds of knowledge related to different forms of popular culture, which is described as bodies of knowledge, skills, and practices derived from viewing, reading, or listening to mass media and popular cultural texts. However, popular culture was the subcategory with the least number of references coded. This means that popular culture funds of knowledge were not mentioned frequently by the participants. One possible reason is that most of the texts and media were obtained from digital technologies and were therefore coded under the digital technology funds of knowledge subcategory. Nonetheless, popular culture was at times a vehicle for conversations that facilitated engineering-related discussions (cf. Moje et al., 2004).

For example, YouTube videos were a source of information that helped participants engage in discussions about their community-based engineering design problems. Tomas explained how a YouTube video was informative in the sense that it helped him understand how headrests are made. Tony explained during an interview the content of the video he watched:

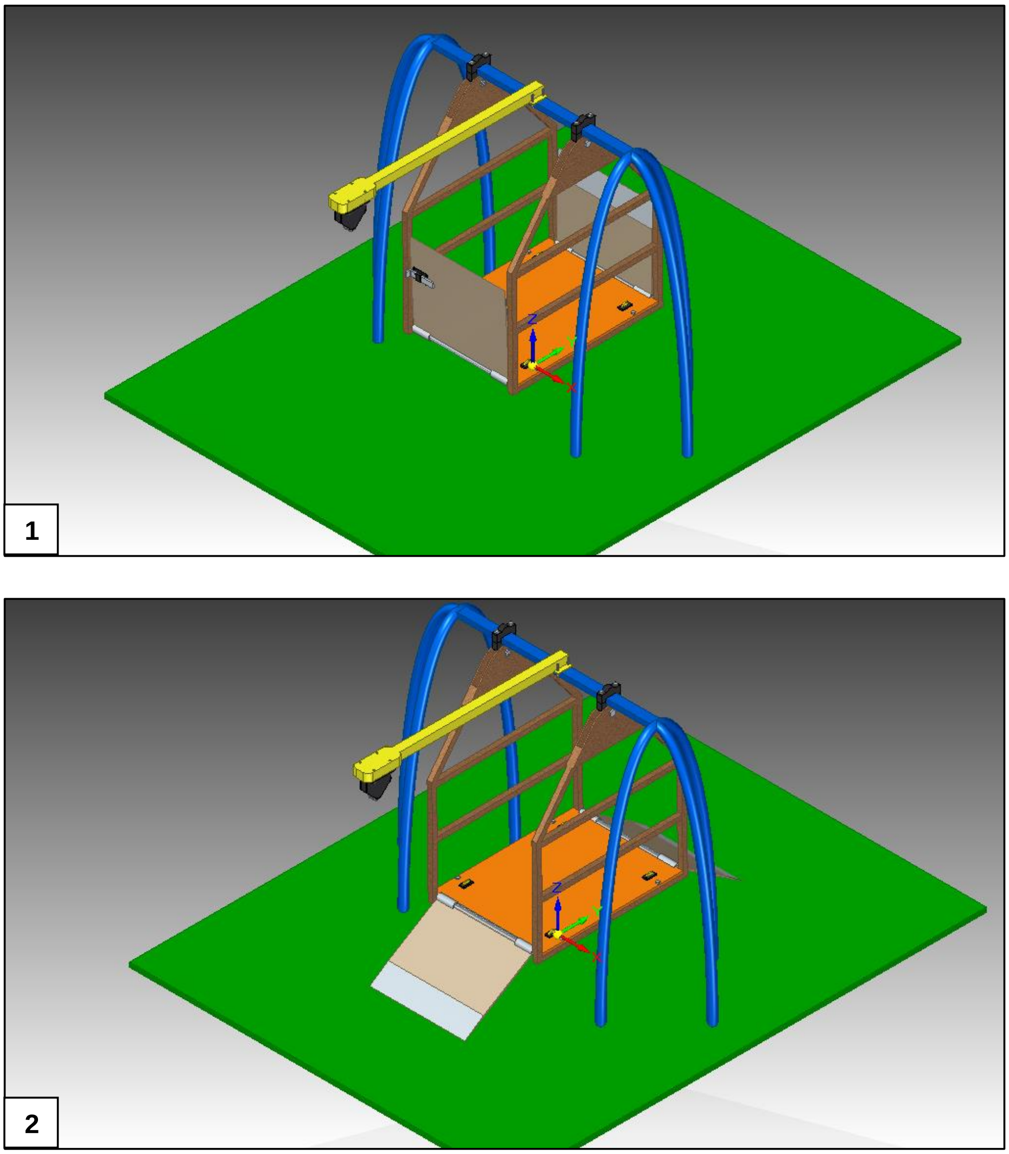

Figure 5-8. Images of final wheelchair swing designs created with solid modeling software. Image 1 shows the locations of the ramps when closed, while Image 2 shows both ramps when open.

> There is this one guy [on the YouTube video]. He added something into the fabric. It was harder. They just had the normal headrest, but there was something they put inside, I don't remember what it was, to make it stay in place. They talked about how it was made. What's all in it. You see, they got fabrics and stuff – they have different materials. They cut one open to show what's inside and how it looked, so I've seen those – To see, to have a visual, not reading about it. If you read about it, you can think about how it is, but in videos you actually see it. I just wanted to see how they are.

According to Tomas, the individual in the video showed how headrests were made and showed the different materials used to fabricate headrests. Tomas also pointed out that the inside of the headrest had different fabrics but also a type of material that made it "stay in place." Tomas was curious about how headrests were made because he wanted to "see it" and not just read about it. Popular culture sites, such as YouTube, became a vehicle for learning, and Tomas gained important knowledge from this source that was later transferred and applied to his community-based engineering design project.

Based on what he learned from the YouTube video, Tomas discussed with his teammates how to approach the construction of the headrest. They decided to go to a local arts and crafts store in their community to identify materials that could be used for their design. Tomas talked about what he had seen on the YouTube video and the adolescents looked for materials similar to those Tomas observed in the video. They selected a vinyl material that would make the headrest waterproof. Because the video also showed that there were different layers of materials to make up the headrest, the group tried to find materials that were similar to those shown in the video. They noticed that after selecting the materials it would be difficult to give shape to the headrests and that they would need a strong material to provide that type of shape and support. Tomas reminded them that the video showed some type of material that made the headrest "stay in place." Later on, Tomas indicated that it was some type of "metallic thing." Thus, the team members agreed on using a piece of metal that would be used to give shape to the headrest. After all the materials were selected, the participants attempted to create a prototype of the headrest using those materials. As shown in Figure 5-9, Tomas and his team used the vinyl fabric, foam, and a copper wire to give shape to the headrest.

Sandra suggested "making it like a burrito," so they placed the copper wire on the piece of foam and rolled it "like a burrito" in an attempt to create a model of the headrest. Informed by the YouTube video, Tomas's group engaged in different engineering-related activities such as *generating ideas*, *evaluating solutions*, and *modeling*. These design processes were similar to those described by Atman et al. (2007). The participants generated ideas regarding the type of materials that should be used and described the step-by-step process to construct a prototype of the headrest. Tomas shared with his teammates what he had learned from the YouTube video. He reminded them that the headrest needed some type of material that could make it sturdy and "make it stay in place." Tomas also indicated that the headrest on the video contained different "layers." The team members tried to recreate the structure of the headrest by finding different layers of materials.

The participants also evaluated solutions by looking at the physical characteristics of the materials they found at the arts and crafts store. They wanted to make sure that the material of choice would be waterproof. They asked several questions to the store

Figure 5-9. Images of the materials used for the headrest. Image 1 shows the foam material selected by the team to be used for the headrest. Image 2 shows how the team envisioned constructing a prototype of the headrest by rolling it “like a burrito.”

attendant to verify that the materials they selected were waterproof. Another evaluation criterion was the price of the materials chosen. The participants looked at alternative inexpensive materials in an effort to generate an affordable product. Finally, the adolescents also attempted to create a model of the headrest using the materials available (Figure 5-9). They used different materials that were used as layers for the headrest and rolled it “like a burrito” to have a visual of what the headrest could look like. As described earlier in the family funds of knowledge, Sofia created a prototype of a “pillow” using the materials bought at the arts and crafts store.

Sports. The last subcategory that emerged from the recreational funds of knowledge was sports. This subcategory was defined as the bodies of knowledge, skills, and practices derived from participating in organized or informal sports teams or communities. Practicing sports became a source of knowledge in various forms. Although Moje et al. (2004) and Moll et al. (1992) did not explicitly describe sports as a category of funds of knowledge; they indicated that peer-mediated activities were significant spaces where funds of knowledge emerged. Within this study, one peer-mediated activity in a formal setting was when adolescents were coached on a specific sport.

Patricio had been training as a soccer player for many years. He started playing in Honduras, his home country, and continued to play for his high school team in the United States. Through the years, he learned that some shoes were better for playing soccer depending on the type of field and the type of cleats he used to play. He explained during group discussions that cleats have “stubs” on the soles for “grip” and prevent slipping. Patricio described why some shoes were better for different surfaces:

> If we're talking about shoes – for cleats, they have the big [stubs] in the grass so they can get good grip, but then there's the running shoes that are more smooth, and they'll have any of the little things sticking out of the bottom. For *futsal*, I mean for indoor soccer – well for the turfs, because sometimes if you have the big [stubs], they can ruin the fields so they came up with the small [stubs]. They're the same but they have a lot more and they're smaller.

Patricio explained that when playing on turf or grass, the players needed to wear cleats that had "big [stubs]" on the soles. The stubs created good grip and they were better for that type of field. He also compared the cleats used for *futsal* to those used when playing on turf. *Futsal*, or *fútbol de salón* as it is known in Spanish, is a variant of soccer that is played usually indoors and on a smaller playing field where the surface is typically wood instead of grass or turf and protected with a resin layer.

These experiences in sports were assigned the engineering code of *evaluating solutions*. Patricio's descriptions indicated that he had become familiar with activities that required him to evaluate solutions based on physical characteristics of the shoes and the surface where he played. Practicing soccer became a way for Patricio to learn more about why shoes have different designs depending on the purpose of the shoe. Patricio evaluated the design of the cleats as appropriate for some contexts but not others. He indicated that the cleats are good for grass or turf because the big stubs provide good grip for the players. The stubs can "stick" to the ground. However, those types of cleats would not be appropriate for *futsal* because the surface of the field was not made of grass or turf. In addition, the cleats with big stubs could not be used for *futsal* because they could damage the resin on the surface of the playing field. Instead, the cleats used in *futsal* have smaller stubs to make the soles "more smooth" and help protect the surface of the playing field. Patricio learned that it is important to consider the purpose of the design and the context of the situation when generating solutions.

Patricio used his knowledge about cleat designs to *generate ideas* for his community-based engineering design project, which was to design a waterproof shoe. Most of Patricio's ideas were related to what he had learned about cleats while playing soccer. For example, during the *problem definition* stage, a fellow group member argued that they would need soles for the shoes that could prevent people from slipping on the ice. Samuel mentioned that they would need soles that created some kind of traction to prevent it. Samuel had also played soccer and thought that soles similar to those of cleats could help prevent slipping. However, Patricio disagreed and said:

> I was running with my cleats. I almost slipped like three times. I slipped once. Because the cleats have no traction whatsoever when it comes to running in just pavement or just – like running in this kind of smooth surface.

Patricio explained that using soles similar to cleats would not work on smooth surfaces because they would not create enough traction and would make it easier to slip. Thus, they decided to design the soles of the shoes similar to the soles of cleats used for *futsal* – small stubs that were close together to create the same type of traction those cleats have on smooth surfaces.

As indicated by this example, Patricio offered important information and suggested a plan of approach based on the constraints of the problem (Moore et al., 2014). Patricio *generated ideas* and alternative solutions to the problem based on his experience observing the physical properties of different designs and their performance under different circumstances. For instance, he evaluated the solution element suggested by Samuel which was to incorporate stubs to the design of their shoe. Samuel argued that a design similar to the soles of regular cleats could provide good traction and prevent slipping because the stubs in the soles were designed to “stick” to the ground. However, Patricio knew that different designs worked only under certain circumstances. He indicated that cleats were designed differently because they served different purposes. Patricio evaluated the designs using his experiences and explained to his teammates that stubs do not always provide traction. He mentioned that having cleats and running on a relatively smooth surface was not appropriate, and instead of creating traction these conditions increased the chances of slipping.

Summary of recreational funds of knowledge. The data showed that recreational funds of knowledge are very diverse. Some of the examples included learning about science and mathematics from iPad applications, soccer, skiing, and online platforms. The availability and accessibility of resources from the internet was one of the topics generally discussed by the participants. Also, the internet became one of the preferred sources of information for many of the participants. The information gathered from the internet and other recreational funds of knowledge became a vehicle for engineering-related conversations.

In addition, it was observed that sports were a significant fund of knowledge for the adolescents. They used the knowledge gained through sport to generate ideas for their community-based engineering design problem. Overall, the participants used their recreational funds of knowledge to engage in engineering-related practices such as *evaluating solutions*, *generating ideas*, *modeling*, and *communication* among others.

Community Funds of Knowledge

The codes related to community funds of knowledge were organized using a similar method employed to categorize the family and recreational funds of knowledge. The data were analyzed through induction where important groups of data were narrowed into smaller sets or categories (Bloomberg & Volpe, 2012). These sets of data were clustered into two main subcategories: (a) community resources and organizations, and (b) volunteerism and community service. The purpose of this section is to present the funds of knowledge emerging from social networks and through the exchange of resources or bodies of knowledge (Gonzales et al., 2005; Moll et al., 1992). Also, included in these subcategories of community funds of knowledge are the bodies of knowledge developed from formal and informal social interactions (Moje et al., 2004). Following is a discussion of the finding regarding community funds of knowledge along with representative examples extracted from the data set that support and explain each finding. Moreover, each subcategory contains the engineering codes embedded in these community funds of knowledge.

As shown in Table 5-4, all of the participants mentioned community funds of knowledge (n = 77) during interviews or group discussions. The participants' community funds of knowledge included experiences with community groups or volunteering in different organizations. Several school-affiliated organizations were classified as community groups such as the rocketry group, Mathematics, Engineering, Science Achievement (MESA) group, or Latinos in Action. These organizations were considered significant because of the formal and informal activities with peers taking place in these organizations, which offered the potential of gaining bodies of knowledge and skills

Table 5-4.

Number of Instances When Each Participant Mentioned Community Funds of Knowledge (n = 77)

Participant name	Number of instances
Samuel	9
Sofia	7
Sandra	7
Clarisa	6
Claudia	6
Emiliano	6
Paula	5
Alejandra	5
Tomas	5
Katy	5
Andrea	4
Patricio	4
Carmen	4
Felicia	2
Dulce	2

through social networks (Moje et al., 2004). Although some adolescents showed a higher number of instances mentioning community funds of knowledge, all participants were involved in some kind of after school activity or volunteered with different organizations.

As provided in Figure 5-10, the participants drew from community resources and organizations more often than they drew from their experiences with volunteering. As the teams were working on their community-based engineering design problem, some of the teams reached out to community organizations to learn more about the problem or to gather information, thus increasing their number of times the data were assigned the *community resources and organizations* codes.

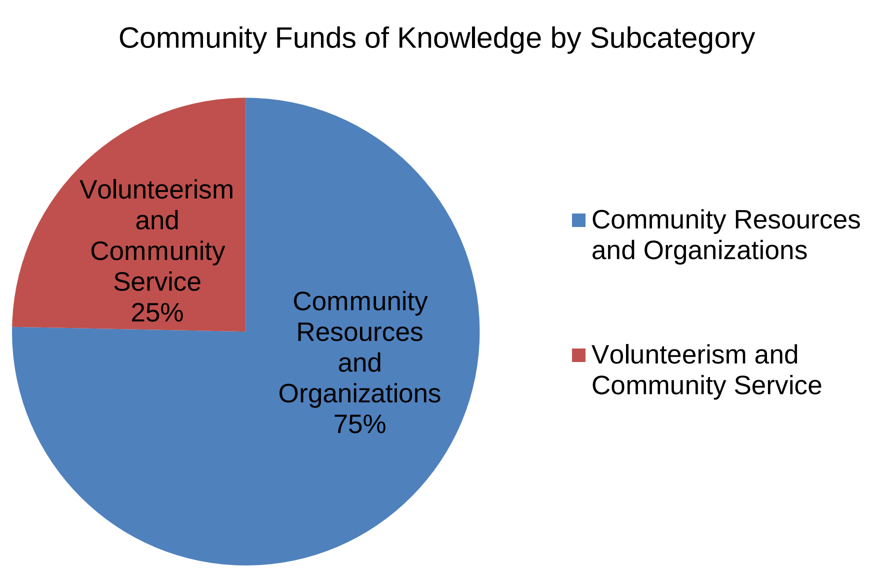

Figure 5-10. Incidence of community funds of knowledge by subcategory (*n* = 77). This pie chart was obtained from the number of instances when participants mentioned community funds of knowledge.

Community resources and organizations. This subcategory includes community organizations, such as Youth Council, as well as school-affiliated groups that held out-of-school activities. All participants were involved in one or more school-affiliated organizations or had participated in these organizations before. Based on these observations, I defined community funds of knowledge as the bodies of knowledge, skills, and/or practices derived from experiences with community groups. The findings described in the following paragraphs support the relevance of community funds of knowledge and their significance in building a wide range of knowledge for the participants. The engineering codes embedded in their community funds of knowledge are also described, thus showing how participants used these funds of knowledge to work on the community-based engineering design problems.

Findings showed that, as Moje et al. (2004) indicated, informal and formal out-of school activities bring a wealth of knowledge opportunities. For example, Clarisa was involved in the rocketry club at her school and later on she got involved in a BioTech camp project with a professor in the community. This project could be considered as a formal peer activity mediated by an adult where Clarisa learned about science and the scientific method. Clarisa participated in a summer camp where she helped in the lab and learned about green fluorescent proteins (GFP).

Later on, she applied that knowledge to her science fair project. She studied two different plants using GFP and studied their “stress signals” to see the “difference or maybe a correlation as to why one of [the plants] is sexual and the other one is apomictic.” Clarisa explained that when plants are apomictic they reproduce by apomixis. This method of reproduction was beneficial because, in Clarisa’s words, “apomixis is important because you don't need to fertilize so it would be really helpful for crops nowadays."

As indicated by this example, Clarisa gained *scientific knowledge* by participating in a community organization and was able to apply that knowledge to work on her own science fair project. Clarisa "engineered a protein into a plant" for her science fair. She "developed a reduction-oxidation sensitive" green fluorescent protein to study the stress signals of the plants. She said during an interview, "I was hoping there would be like a difference or maybe a correlation as to why one of them is sexual and why the other one is apomictic because they can revert." She learned about concepts regarding plant reproduction and the use of green fluorescent proteins to monitor and influence plant behavior. Based on the bodies of knowledge and skills learned at the summer camp, Clarisa went above and beyond to try to improve crop production.

I coded Clarisa's experiences in the summer camp as *scientific knowledge* – one of the codes related to bodies of knowledge, dispositions, and habits of mind relevant to engineering. Clarisa approached an engineering task by applying scientific concepts she learned during the summer camp. This application of scientific principles aligns with Moore and colleagues' (2014) belief that high school students should learn to apply scientific concepts to solve challenges.

Moreover, Clarisa also participated in the rocketry club – an after school program – where she learned about other scientific concepts such as pressure. She said in an interview, "I learned about pressure because of my rockets because you need different pressure amounts to get different heights and stuff." Working with rockets and learning about how they operate was a source of knowledge for Clarisa as she learned different physics concepts. Clarisa related scientific concepts such as height and pressure to make her rockets work. This is an example of a peer activity mediated by adults that resulted in Clarisa’s analysis of rocket elevation as related to the amount of pressure that the rocket could create.

Interestingly, Clarisa used the scientific knowledge gained through her rocketry club– the concepts of height and pressure – to generate ideas for the water catchment system. She talked to her teammates and indicated that the container for the water from the catchment system needed to be at a certain height. Although the team decided not to connect the water container to the plumbing system of the house because it would be more difficult to implement and more expensive, Clarisa reiterated that even if the container stayed outside it should be placed at a certain height to eliminate the need for a pump to collect the water. During a group discussion she said:

> So if we have the container just right next to the house – it goes from [the gutter] into the container and since it’s downhill, you don’t need any pressure to get it into the container. So the container is going to have water and the water – the water in there is going to cause pressure to push it out so when you open the faucet the water is going to run. So if you have a sink inside you’re not going to need like a pump to push the water, it’s just going to – the pressure is going to do it for you.

What Clarisa was referring to in this excerpt was the need to create some type of hydraulic head to allow the water to flow from the inside of the container to the outside of the container without using a pump. Although she did not specifically verbalize this concept as hydraulic head, Clarisa understood the concepts of pressure, height, and their effect on fluid flow. Based on her *scientific knowledge* of pressure and height, Clarisa generated ideas that could be implemented to the design of their water catchment system. She knew that by elevating the tank and placing it at a certain height, water could flow out of the tank through the “spigot” because the pressure would “push” the water out. As shown in Figure 5-11, Clarisa’s team decided to elevate the water container for their design. After doing some internet research, they chose to use cinder blocks to elevate the water container and create the necessary “pressure” Clarisa talked about. Paula indicated that they should not use wood to keep the tank elevated because “the wood would die off quickly – it’s too humid.” Then, Alejandra suggested using “concrete bricks – the ones made of cement but they have two holes.”

After doing some information gathering using the internet, Alejandra found out that “concrete bricks” (cinder blocks) could hold up to 500 pounds when placed horizontally. Therefore, they decided to use two layers of cinder blocks to elevate the water container enough to create the hydraulic head. Also, Paula gathered some information from her relatives in Honduras regarding the regular water consumption rate per day per person, the dimensions of an “average” home, and the “average” size of a family in Honduras. The dimensions shown in their final sketch in Figure 5-11 were obtained after the participants did some internet research and combined that information with the data gathered by Paula.

This example described the bodies of knowledge, skills, and practices derived from experiences with community groups. In this case, Clarisa learned about different scientific concepts from her rocketry club and her summer camp experience. She shared her knowledge about pressure and height with her teammates, thus persuading them to

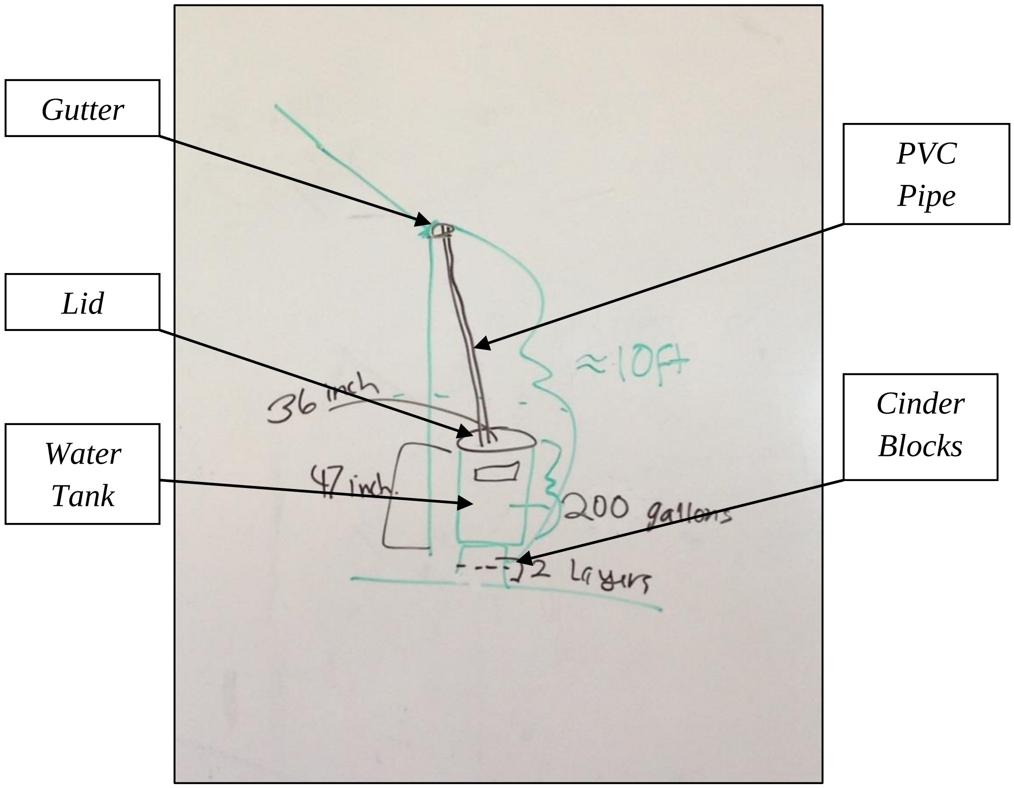

Figure 5-11. Participant-generated sketch of a water catchment system. The image illustrates a model featuring all attributes considered by the participants – gutters, PVC pipe for water collection, lid for the water tank, a water tank with a capacity of 200 gallons, and two layers of cinder blocks to keep the water tank at a certain elevation and create hydraulic head.

think differently about the scope of the problem. As stated before, Clarisa exemplifies how experiences with community groups can become learning spaces where adolescents can obtain scientific and mathematical knowledge. Clarisa used the knowledge gained through her experiences with community groups and applied it to her community-based engineering design problem. Clarisa brought into the group discussions topics that involved scientific knowledge. As indicated by Atman et al. (2007), problem scoping is a critical element of engineering design where students frame their project goals and identify the needs. Integrating scientific concepts to their design helped the participants define the problem and formulate a new plan of approach that combined new solutions to the problem without compromising their main objective – to make a cost-effective water catchment system.

Clarisa's example demonstrates that knowledge generated through community resources and organizations is important, and this knowledge provided the participants with tools to engage in engineering-related conversations. Although Clarisa learned about scientific concepts from a formal after school organization, other participants learned scientific concepts from more informal networks. Moll et al. (1992) argued that social networks and systems of exchange are important sources of bodies of knowledge. Social networks and systems of exchange are "flexible, adaptable, and active, and may involve multiple persons from outside the homes" (Moll et al., 1992, p. 133). During the study, all participants were encouraged to reach out to people in their community in order to gather information about their engineering problem. Some of the participants talked to professors at the local university, visited nursing homes, or gathered information from local stores to learn more about the materials they intended to use.

For instance, Samuel drew from an informal social network in his community when he learned about the production and processing of sporting goods through one "family friend." His father, a local university professor, had an ex- who took him for a tour of the company where he worked. Samuel said during an interview:

> Last fall I went to Portland with my dad. He has an ex- that works in logistics with [a sportswear company]…We went to the headquarters and saw all the design things they had that they were working on…What I learned the most is I didn't see a single person working on their own. Everyone was working on a team

> of at least two people. Everyone was collaborating. They had a conference room a little bit bigger than this where they had a giant whiteboard with drawing and talking about different things. I think it was the teamwork I noticed.

Samuel explained that, through this experience, he learned about the interactions between employees at the sportswear company. He indicated that, even though he saw all the designs and toured the production area, one of the main learning lessons was that teamwork was very important to design and create a product.

Samuel later indicated that he learned the difference "between industrial designers and engineers" during his tour. He said he "spent a day with the designers to see how they typically design things and stuff." He also noticed different characteristics of the workplace and indicated the following during an interview:

> [The employees] split themselves into designers and engineers. So they'll have the designers, and they just draw things. They start seeing how things should work. Then they send it on to the engineer. He'll decide what the material will be made of, the density of the material. All these different factors. Everything has to be perfect.

Samuel had an experience that allowed him to see how a team of engineers work together to achieve certain goals. He also learned that individuals' expertise and characteristics are necessary to efficiently complete a task, such as the expertise of designers versus the expertise of engineers. He talked about the difference between the roles of an industrial designer and an engineer. From his experiences, Samuel learned that industrial designers are involved in the "creative process" while the engineer executes the ideas proposed by the industrial designer.

I assigned the engineering code *teamwork* to his description because Samuel learned about how engineering required collaboration and division of labor. He explained that engineering was heavily influenced by teamwork and roles were divided among individuals. Samuel learned that part of being an engineer and working in production requires working with other individuals in order to make everything “perfect.” Moore et al. (2014) indicated that engineering education should teach students how to use teamwork to achieve a common goal. Samuel’s interactions with his social networks demonstrate that community resources and organizations are an important fund of knowledge. Knowledge obtained though social networks is a good example of how students learn by being active participation (Moll et al., 1992). As Samuel and Clarisa’s examples suggest, students can use what they learn from community resources or organizations and apply this knowledge to solutions to engineering design problems.

Volunteerism and community service. The commitment to help others was a recurrent theme in this study. Moje et al. (2004) suggested that a “commitment to social and community activism” provides students with a space for learning (p. 55). Similarly, the analysis of data in this study showed that the participants developed relevant engineering knowledge through engaging in community-based organizations that provided service to others. Thus, volunteerism and community service emerged as a subcategory under the community funds of knowledge category. A majority of the participants had previously engaged in community-based organizations that provided free services to the community. Some of these activities included volunteering at nursing homes, participating as tutors for students with physical disabilities, or contributing to church-based programs. The adolescents became aware of different problems in their community after participating in these community-based organizations. In fact, some of the problems they chose addressed issues they had witnessed as volunteers.

For example, Carmen volunteered as a tutor at her school and worked with students with physical disabilities. She persuaded her team members to design a swing that could be used by individuals in wheelchairs. Carmen talked about her decision to work a project that could bring some joy to the students she tutored. She was concerned about the few options many students with physical disabilities had when they went to the local park. Carmen indicated that the community park was not accessible for the students she tutored and the options for recreation for many of these students were minimal. Playgrounds in her community did not include any accessible play structures where kids with physical disabilities could play. Consequently, many of the students in wheelchairs felt left out.

During her volunteering experience, Carmen learned that many of the students needed assistance in some way or another and having a sense of “independence” was extremely important for them. She said during a group discussion:

> They can’t go to the bathroom without assistance and I feel like all they try to be like us, like “normal,” you know? And they try hard to but they really can’t because they know that. [A student] wants to be like us, so when we would go on walks, or play with her ball, she didn’t want to be in her walker. She just wanted to fit in I guess.

Carmen’s exceptional sense of responsibility to the well-being of others in her community demonstrated her commitment to vulnerable populations. Her descriptions were coded as *empathy and ethical considerations*, which is an important disposition for engineers to have. Ethical considerations and empathy are important to engineering because engineers frequently have to design products or systems for individuals who are different from them.

In other words, the engineer needs to empathize with the conditions and experiences of the clients in order to meet their needs even if the engineer has never had those same experiences. Carmen empathized with the students with physical disabilities she tutored. This empathy led her to develop a swing that would give the students a sense of “independence.” Carmen persuaded her teammates to design a swing that would be safe and easy to access. This team wanted to provide a solution to the problem while addressing ethical considerations that included safety and the health effects of their design (Moore et al., 2014). The team agreed that “making the students feel normal” would be extremely beneficial for their health in terms of self-confidence.

Although most adolescents related their volunteering activities to their commitment to the well-being of vulnerable populations, other participants’ volunteering experiences were a source for scientific knowledge. For example, Sandra learned about preventing the spread of diseases through her volunteering experience at a local nursing home. Sandra explained that preventing the growth of bacteria was extremely important to keep the patients at the nursing home healthy. She indicated that some individuals are prone to getting sick because of their age. Therefore, one of the main concerns was the accumulation of bacteria in different areas of the nursing home.

Sandra explained that everyone at the nursing home had to be very careful when helping the patients and not let any type of fluid get in contact with other individuals. She explained in an interview different preventive measures while working with patients:

> Every single time we get done with a patient we wash our hands because…if you touch someone and they have an open wound, whatever you touched goes onto there. If you don't wash your hands, [the bacteria] could go around. So you have to be really careful when you go into the patient's room because you don't want to leave the bacteria there. And then we always use gloves in every single time, like for any situation. Let's say I use the gloves for a certain thing, you don't – even if you had the same client – we don't use the same gloves for that, for a different situation. Just for the fact that whatever you touched could also get infected even if you have gloves. The bacteria could still be in the gloves. So we use a lot of gloves.

Sandra described that the use of gloves was very important; however, even when using gloves she had to wash her hands constantly. She learned that bacteria can stay in the surface of the gloves and get transferred to a patient if that patient had an open wound. Sandra also indicated that she had to change gloves every time she handled different items and for every "different situation." Through this experience, Sandra became involved in a science-related community action (Moje et al., 2004), where she learned about ways to prevent the spread of diseases or infections.

Later on, Sandra used her *scientific knowledge* about infectious diseases to *generate ideas* about the materials that should be used to make the shower chair headrest. Sandra indicated that there were specific materials that allow bacteria to grow easily and that it could impact the health of the patient. According to Sandra, individuals with Duchenne Muscular Dystrophy were more prone to get infected or get sick. Therefore, it was important that her group used a material that could prevent the growth and accumulation of microorganisms. Sandra observed at the nursing home that she had to follow a lot of “safety hazard” procedures. She said, “When we wash our hands, we do it like this special way where you don't have to – you can't lean into the sink, or else you get bacteria on your clothes.” Sandra had to follow different procedures to make sure that her scrubs did not touch other patients because bacteria could be transferred that way. She talked about how bacteria can go from one patient to another “when your scrubs touch the patient and it goes around.”

Based on these experiences with the materials she wore while volunteering, Sandra believed that the material for the shower chair headrest should be waterproof so that it could stop the growth of bacteria. While volunteering at the nursing home, Sandra noticed that many of the walkers and shower chairs were made out of materials that prevented the accumulation of water. The reason behind using a waterproof material was that it also impeded the bacteria nucleation sites. Thus, Sandra gained *scientific knowledge* from her experiences with volunteering, and she applied this knowledge while her team designed the shower chair headrest.

Summary of community funds of knowledge. Community resources and organization became sources of knowledge for the participants as they engaged in different activities with different groups. The findings showed that the adolescents engaged in both formal and informal peer activities. The participants also drew from the knowledge and skills gained through these experiences to solve their community-based engineering design challenges. The participants’ life experiences helped them through the engineering project. They applied the *scientific knowledge* gained through their involvement with the community. They also drew from the knowledge and skills obtained from community groups to approach the engineering problem by *generating ideas*, *evaluating solutions*, and *working as a team* among others.

Similarly, the adolescents also drew from the bodies of knowledge and skills gained through practices associated with serving others to work on the community-based engineering design problem. The participants talked about their commitment to the well-being of vulnerable communities and addressed problems they observed through their volunteering experiences. The adolescents' practices with community and volunteer groups helped the participants create strong links between their experiences and engineering-related activities.

Summary of Findings

This chapter described different instances when the participants mentioned funds of knowledge. The analysis showed that there were engineering-related codes embedded in the adolescents' funds of knowledge. All participants provided solutions to their problems based on several life experiences. There were several participants that identified with the self-selected problems in one way or another.

The two research questions of this study were addressed. The first research question – What engineering-related funds of knowledge do Latino high school students have? – was addressed by looking at the funds of knowledge of the Latino adolescents. The findings presented in this chapter showed that the participants possessed funds of knowledge that aligned with some aspects of engineering Discourse. These funds of knowledge encompassed three main categories: (a) family funds of knowledge, (b) recreational funds of knowledge, and (c) community funds of knowledge. The participants talked about bodies of knowledge, skills, and practices related to family funds of knowledge more frequently than the other two categories. In addition, the participants also demonstrated that their funds of knowledge contained embedded engineering-related codes such as the *use of tools*, *modeling*, *communication, problem definition*, *generating ideas*, *production and processing*, *scientific knowledge,* and *ethical considerations and empathy* among others.

The second research question – How are these funds of knowledge used to address a self-selected community-based engineering design problem? – was addressed by looking at the way the adolescents applied their funds of knowledge to provide solutions to their community-based engineering design problems. The analysis indicated that the participants constantly used their funds of knowledge in different ways to generate solutions to their problems. The participants drew from different bodies of knowledge, skills, and practices derived from their funds of knowledge to engage in engineering Discourse. By doing so, the adolescents provided alternative solutions to problems they had observed in their community.

CHAPTER 6

DISCUSSION AND IMPLICATIONS

The purpose of this study was to investigate the funds of knowledge of a group of Latino high school adolescents and how they used their funds of knowledge to solve community-based engineering design problems. This study was designed to learn more about the adolescents' everyday practices, skills, and bodies of knowledge through an ethnographic approach. The participants were grouped in different teams and they selected a specific community-based engineering design problem. Through interviews, group discussions, and observations, I attempted to unveil and interpret their funds of knowledge as they worked on their community-based engineering design problem. Using a *funds of knowledge* framework, two research questions were addressed:

1. What engineering-related funds of knowledge do Latino high school students have?
2. How are these funds of knowledge used to address a community-based engineering design problem?

Students drew from a variety of resources from their everyday lives to provide solutions to the problems they selected. This chapter summarizes the findings and conclusions from this research. The discussion is followed by the implications of the study and a final reflection from the researcher.

Participants' Funds of Knowledge

Three different categories related to funds of knowledge were identified – family, community, and recreational funds of knowledge. Each category contained different subcategories that emerged from the data analysis. Four subcategories originated from the family funds of knowledge category – workplace, international travel, health, and household management. These four subcategories included bodies of knowledge, skills, and practices that usually revolved around familial activities or around workplace activities whose purpose was to provide financial support for families. The participants were actively involved in household chores, repairing and/or building items, traveling to other countries, living in other countries, and learning about household management. As Moll et al. (1992) indicated, the adolescents were not "passive by-standers" and their knowledge was obtained by being active participants in different practices (p. 134). Most of these funds of knowledge had some commonalities across all participants.

These funds of knowledge are distinctively accumulated historically and culturally (Moll et al., 1992; Velez-Ibañez & Greenberg, 1992). For example, previous research (Moll et al., 1992) indicates that health and household management bodies of knowledge, skills, and practices have transferred from generation to generation. On the other hand, some funds of knowledge, such as those within the international travel subcategory, were distinctively regional. For instance, participants who had lived or travelled constantly to Central America shared some of the same experiences, bodies of knowledge, and skills learned from participating in activities in that particular region. Thus, the source, range, and diversity of family funds of knowledge varied even within the same theme.

Family funds of knowledge were the source of most of the emerging bodies of knowledge, skills, and practices. One of the most interesting family funds of knowledge subcategories was household management. It was one of the most frequently mentioned and used source of knowledge when working on the community-based engineering design problem. The household management subcategory covered a source of knowledge that encompassed a wide range of funds of knowledge. The data analysis showed that, in fact, students' active involvement in household management constituted broad bodies of knowledge that students can bring into the classroom and apply to engineering design (see Implications for Classroom Practice section).

The second theme that emerged was community funds of knowledge. This theme was divided into two different subcategories – community resources and organizations and volunteerism and community services. The bodies of knowledge, skills, and practices relevant to community funds of knowledge derived from a strong involvement with community groups. All participants had been involved in some community group before or during the study. Social networks gave the adolescents access not only to bodies of knowledge, skills, or practices, but also to other adults' specific areas of expertise. The adolescents were active participants in different activities moderated by adults or other peers. Moje et al. (2004) described these activities as a space where students are encouraged to explore, learn, and "engage in Discursive practices similar to those demanded in school content areas" (p. 58). Participants' descriptions indicated that they were persuaded to learn and explore while they were involved in formal and informal peer activities through these community groups.

The community funds of knowledge were often tied to the engineering code of "empathy and ethical considerations." Three out of the four teams worked on problems that involved creating a device or system that could benefit vulnerable populations. The students' volunteering experiences became the source of knowledge regarding problems observed in the community. They also learned about the needs of some vulnerable populations and were able to identify ways to address those needs.

Finally, the last category that emerged from the data was recreational funds of knowledge. This category contained three different subcategories – digital technologies, popular culture, and sports. Digital funds of knowledge were some of the most frequently mentioned sources of knowledge. Marsh et al. (2005) emphasized how children from an early age are completely immersed in practices involving new technologies. The study showed that the participants were actively engaged in learning from new technologies. Digital technologies provided the adolescents with a space and resources for scientific conversations.

On the other hand, sports and popular culture were two of the least mentioned funds of knowledge. When popular culture was mentioned, it was closely associated to digital technologies. Most of the mass media and popular cultural texts mentioned by the students were tied to digital technologies in some way or another. Sports became significant for the team that designed the shoe because most of their approaches to the community-based engineering design problem were based on their bodies of knowledge, skills, and practices relevant to sports.

Connections Between Funds of Knowledge and Engineering-Related Practices

The data analysis suggested that the participants engaged in practices related to the engineering discipline. Although their funds of knowledge were not engineering specific, the adolescents' funds of knowledge related to those carried out by engineers. The codes related to engineering design processes included problem definition, information gathering, generating ideas, modeling, evaluating solutions, communication, and realizing solutions. The codes related to bodies of knowledge, dispositions, and habits of mind relevant to engineering included scientific or mathematical knowledge, systems thinking, production and processing, ethical considerations and empathy, team work, and use of tools. The participants brought their funds of knowledge to bear on their community-based engineering design problems. The following description of one team's engineering activity will synthesize the findings from the previous section by summarizing how different funds of knowledge were used at different stages of the design process.

Tomas' group defined the problem based on the needs of Tomas' brother who suffered from Duchenne Muscular Dystrophy. The team members identified constraints and areas for improvement for the shower chair headrest based on the needs of Tomas' brother, a specific audience. They gathered information throughout the project using digital technologies, meeting with community groups, and interviewing family members, among other resources. The adolescents also generated ideas based on their community funds of knowledge, such as the material characteristics suggested by Sandra based on her experiences with preventing the spread of bacteria as she volunteered at a nursing home.

In addition, the adolescents created prototypes and evaluated their solutions using skills learned at home (i.e., Sofia's handmade pillow used as a prototype). The participants realized solutions to the problem by engaging in constant solution evaluation and analyzing trade-offs. Tomas' team compared the materials at the arts and crafts store based on the properties of the materials. They wanted a material that was waterproof but also affordable. They noticed that this was a trade-off because some of the materials were expensive, such as the foam and metal, but seemed to be more durable than the cheaper versions of the same materials.

Lastly, the participants rigorously considered ethics in the process of realizing a solution. One of their objectives was to create a cost-effective solution while providing a social good. The majority of the participants indicated that, from their experiences at home and in other countries, money was one of the main concerns in their families. The students had an understanding of the impact of their solutions in an economic and social context (Moore et al., 2014). Financial resources were a recurrent topic of discussion in the solutions provided by the students because it was important for them to contribute positively to their community – a community with a low socioeconomic status.

The engineering codes already mentioned have been also identified in other studies, indicating that Latino students' funds of knowledge are relevant to authentic engineering design activity. Atman et al. (2007) listed similar codes during a study involving novice and expert engineers. Engineering design processes involved three design stages – problem scoping, developing alternative solutions, and project realization – and ten different design activities. Both design stages and design activities are consistent with the results obtained in this study. Even though eight of the participants had never taken an engineering course, all of the students possessed bodies of knowledge, skills, and practices related to engineering that emerged from their funds of knowledge.

In addition to being related to *engineering design processes,* several funds of knowledge excerpts were simultaneously coded as relating to *bodies of knowledge, dispositions, and habits of mind* relevant to engineering. The participants possessed bodies of knowledge that had a relative engineering value. Moore et al. (2014) provided a framework for quality K-12 engineering education, which contained key indicators similar to those described in this study. All the engineering-related codes emerging from the data demonstrate that funds of knowledge could be relevant for many Latino students in K-12 because they can relate to their everyday lives. The often marginalized experiences of Latinos in K-12 can become the tool to develop conversations relative to engineering.

Implications for Future Qualitative Studies in Engineering Education

Like other studies involving funds of knowledge and science (Barton & Tan, 2009; Moje et al., 2004) and mathematics education (Civil, 2002; Razfar, 2012), this study involved working with minority students using interpretive research. Interpretive engineering education research is relevant and significant to the engineering field (Walther et al., 2013). According to Case and Light (2011), including these methodologies in engineering education is important for the growing field of research in engineering education. This broader range of methodologies can point toward ways in which high school engineering teachers might implement innovative pedagogies.

This study has direct implications for future qualitative studies in engineering education related to issues of underrepresentation. The most prominent implication is that it acknowledges the importance of representing the voice of underrepresented groups through culturally sensitive approaches. This study challenged the perception that Latino adolescents possess motivational and cognitive deficits. This qualitative approach also showed how the interests of Latino adolescents may have deeper connections to engineering-related issues.

An important piece of this study was building relationships with the participants through conversations about their interests. Engaging in these conversations was important to build *confianza* between the researcher and participant. In addition, leading group discussions involved learning more about the participants and facilitating interactions that promoted a sense of independency and self-empowerment with respect to engineering (Riley et al., 2014). For instance, participants were able to relate some of their everyday practices to engineering due to their active involvement in engineering discourses. For example, Felicia mentioned during an interview, “I thought we were going to be told what to do.” Instead, the participants engaged in practices where they had the power to select their own projects and were able to draw from funds of knowledge that related to that project. If the participants had not selected a project that did not relate to their communities or backgrounds, it may have been harder for them to draw from their funds of knowledge on a topic they knew nothing about. Consequently, one implication for future research is to make the participants active and to give them agency or self-determination because multiple participants reported that empowerment was one thing they liked about the project.

Future qualitative research in engineering education can include interviews in the students’ home languages rather than in the dominant language. For instance, some of the discussions and interviews were carried out completely in Spanish in order to help the adolescents feel safe in a more inclusive environment. The conversations in Spanish allowed the students to express themselves in a language they felt comfortable with, thus contributing to positive interactions and the building of trust.

Future ethnographic studies in engineering education can include different data collection methods such as conducting interviews, concurrent and retrospective protocols, and observations. In order to elicit engineering design activity among the participants, it was necessary to get to know the adolescents in multiple contexts. Group discussions, interviews, and concurrent and retrospective protocols allowed the researcher to question the participants more deeply about their practices at home, work, school, and the community. For instance, although the same protocol was followed during every interview, we asked questions that involved not only one dimension of the adolescents' everyday lives. The questions were designed to elicit funds of knowledge from different areas of the participants' lives, ranging from their work lives to the tie they spent playing video games with friends. The questions asked represented a broad range of contexts in which the participants developed different funds of knowledge. This multi-dimensional led to a better understanding of their funds of knowledge.

Implications for Future Research

Other lines of research that stem from this study include creating curriculum materials that integrate Latino students' funds of knowledge, and testing whether these curricular materials lead to gains in their engineering design thinking as compared to a control group. Researchers can also develop case studies that incorporate aspects of the funds of knowledge framework into classroom activities. Case studies can be used to actively involve the students in the learning process using interdisciplinary aspects of engineering (Davis & Yadav, 2014; Raju & Sankar, 1999). Through these case studies, students may be able to analyze practical real-life problems. The problems included in these case studies will be generated by drawing from the students' funds of knowledge. Eventually, curriculum materials can be generated using this approach in order to make attractive, yet challenging, and culturally responsive engineering education materials for K-12 Latino students.

The second line of research stemming from this study is to train pre-service and in-service teachers regarding how to use the funds of knowledge framework and draw from the students' funds of knowledge to create their own teaching strategies. Future researchers can create professional development programs for high school engineering teachers, which address how to provide instruction to linguistically and culturally diverse classrooms. Research (Buxton, Lee, & Santau, 2008; Lee, 2004; Lee, Luykx, Buxton, & Shaver, 2007; Rodriguez & Kitchen, 2005) suggests that many teachers do not have the right training, professional development, materials, and curricula necessary to help bilingual students learn science. Within the field of engineering, these training materials and programs would help teachers understand and appreciate the students' sociocultural experiences, and relate engineering to those experiences.

For example, many scientific and engineering terms are only specific to science or engineering, and these words are not applicable in the students' daily lives and are, therefore, foreign to them. Teachers can receive training on how to help unfamiliar concepts seem relatable to Latino youth. Further research will be conducted regarding effective methods of professional development for high school engineering teachers, which will provide them with the proper training, exposure, and practice to deliver culturally responsive teaching to diverse classroom while being competent in teaching the subject matter.

Finally, an additional line of research can include a closer look into Latino students that have taken engineering courses and those who have not. Although selected purposefully, some of the participants in this study had taken engineering courses in the past while others had not. After coding the data set, it was observed that participants who had taken engineering courses did not use engineering design processes or practices more than the participants who had not taken the courses. Although some of the participants had different educational or socioeconomic backgrounds, all adolescents approached the engineering problem the same way. Participants who had classroom knowledge of engineering did not mention how formal engineering design processes learned at school can be applied to solve a problem. Instead, all participants constantly drew from their funds of knowledge to provide solutions to the problems. If some students had previous knowledge of engineering, why is it that they did not use the classroom knowledge as frequently to approach their problem? Further research could investigate this topic. Another question that emerges from this analysis is how does the school environment influence students' learning or engagement in engineering? Further studies can be done to learn more about classroom environment and dynamics in order to increase student engagement in engineering.

Implications for Classroom Practice

Although this study did not involve an analysis of classroom practices, the findings from this study can be used to inform future research involving funds of knowledge and classroom practices. This section outlines different ways in which classroom practices can be implemented. The examples provided in this section describe possible implications for teaching that stem from the study. However, these implications are somewhat speculative and need to be tested.

For instance, teachers could give surveys to the students at the beginning of the school year. Each survey could be used to ask questions regarding the funds of knowledge categories identified in this study. Some of the questions that could be included in the survey are:

- What sports do you play?
- What digital technologies do you use?
- Have you ever helped your family fix something in your house?
- Have you lived in a community outside the United States?
- How are you involved in your community?

These questions can be used as a form of inquiry where teachers use the students' responses as a basis for teaching engineering. Moll (1994) argued that "existing classroom practices underestimate and constrain what Latino children are able to display intellectually" (p. 179). Through this type of inquiry and sociocultural approach to engineering education, teachers can look into the different resources of the students and create their own innovative instructional strategies that draw from these resources.

One example of how teachers can draw from the students' recreational funds of knowledge is to ask the students to reflect on their sports experiences while discussing relevant engineering and science concepts. For instance, if the students wanted to design a shoe, as in the example described in this dissertation, teachers could guide students through reflecting on their experiences with shoes in sports. Then, the teachers can use this discussion as a basis for teaching scientific or engineering principles related to the shoe design. Also, the students can describe why specific designs are used for specific sports as opposed to other available designs that serve the same purpose. The students can identify similarities and differences about their designs or list the trade-offs encountered in their attempt to improve their designs.

Teachers might draw from students' community funds of knowledge through different methods. For example, teachers can ask students to identify the needs of people within local community groups. Students can go to community organizations and centers that are of interest to them and gather information about items or systems they could improve. Then, the students can be directed to create models of those items or systems and provide a description of how it was improved. The follow-up requirement for the project could be presenting their ideas to relevant community organizations.

Lastly, in addition to drawing from students' recreational and community funds of knowledge, teachers can also draw from recreational funds of knowledge. For instance, several participants in this study talked about sewing practices at home. Students can state what they have learned about "production and processing" or "evaluating solutions" through sewing. They learned, for instance, that sewing involved evaluating different needles and threads and the properties of the fabrics used. They also learned that how something is made could affect whether the product is effective or not. Engineering teachers can ask students to apply the same knowledge to other situations or designs by asking students to provide examples of how production processes can influence the quality of final products.

Although it cannot be assumed that all students will possess the same funds of knowledge, the framework of funds of knowledge is transferable. In other words, other students will have funds of knowledge related to sports, their household management, health concerns, and so forth, which can be used as a platform to introduce engineering concepts. This study does not imply that only Latinos or students of color have rich funds of knowledge emerging from social and cultural experiences. However, school knowledge and Discourses tend to be aligned with the knowledge and Discourses of the dominant culture (Bourdieu & Passeron, 1990; Moje et al., 2004). Therefore, this project is intended to enhance the educational experience of underrepresented minorities whose social and cultural practices have been traditionally undervalued in schools.

This study pointed toward ways in which teachers might bring particular funds of knowledge into the classroom. Although previous studies have shown that Latino students are underrepresented in engineering (National Academy of Engineering and National Research Council, 2009; Riley et al., 2014; Stevens et al., 2005), this study suggests that Latino students possess a wealth of resources that can be used in the classroom. The data from this study outlined fund of knowledge from which classroom instructors might draw to help students direct their learning of engineering design. Although funds of knowledge may vary according to geographical area or cultural backgrounds, the general categories of the framework may remain consistent. Previous studies suggest that funds of knowledge remain consistent across contexts, with a few minor changes (Barton & Tan, 2009; Gonzalez et al., 2005; Moje et al., 2004), thus indicating that Latino students' funds of knowledge may likewise remain consistent with minor changes. One possible model for application is to create curricular materials that can include case studies using community-based challenges, which are designed to draw from the students' funds of knowledge. This approach would require instructors to get to know the students better and learn more from their interests and experiences before the case studies can be developed and implemented.

Although this study points toward Latino students' funds of knowledge, it is not meant to suggest that funds of knowledge frameworks are sufficient for preparing students for engineering careers. For instance, some of the participants held scientific or engineering misconceptions when applying their funds of knowledge. Nonetheless, future research can determine an effective *funds of knowledge approach*, which begins with students' interests and uses those interests as a basis for teaching science and mathematics as applied to engineering.

Significance of Findings

Although literature exists on funds of knowledge in science and mathematics (Barton & Tan, 2009; Civil, 2002; Moje et al., 2004; Razfar, 2012), this study is one of the first of its kind of funds of knowledge in engineering. These findings contribute significantly to the funds of knowledge literature and engineering education at the K-12 level. These findings provide a framework for researchers and instructors involved in culturally responsive engineering education. Teacher can draw from the students' at-home experiences, practices, and interests to create engineering design activities that are more inviting to Latino students. This work builds upon Moje and colleagues' (2004) idea of drawing from marginalized students' Discourses and knowledge to create new classroom practices. This practice includes the implementation of a funds of knowledge approach to engineering education.

The participants' unique funds of knowledge also support the key indicators needed for a quality engineering education at the K-12 level (Moore et al., 2014). In addition, the students showed their ability to connect their everyday lives to engineering processes (Achieve Inc., 2013). Although previous research has indicated that Latinos are an underserved and underrepresented population in engineering (Foor et al., 2007; Riley et al., 2014; Seymour & Hewitt, 1997; Stevens et al., 2005), this study suggests that they possess bodies of knowledge, skills, and practices that are directly relevant to engineering. Teachers can use funds of knowledge as an instrument to initiate conversations that help Latino students engage in engineering and engineering design practices.

Previous research (Barton & Tan, 2009; Barton et al., 2008; Civil, 2002; Moje et al., 2001) has suggested that a funds of knowledge approach has a positive impact on Latino students learning in science and mathematics. By implication, this approach might have a positive impact on Latino students' learning in engineering, although future research is needed to test this assumption. However, this study moves the field of engineering education toward culturally responsive practices by providing teachers with an idea of the funds of knowledge they may draw from to make engineering more inclusive. These practices may allow the students to stretch their learning and allow their teachers value the bodies of knowledge and skills that the students bring into the classroom.

It is important to emphasize that the everyday life experiences of Latino students may be able to enhance the field of engineering because it is through diversity that future engineers will be able to address different problems in a social, cultural, and economic context (National Academy of Engineering, 2002; Williams & O'Reilly, 1998). Although the research team did not evaluate the quality of the students' final solutions, each team suggested a solution that incorporated knowledge of scientific, socioeconomic, and cultural issues. The students engaged in engineering-related practices, thus showing that the wealth of knowledge and experiences that Latino students bring into the classroom, which can be incorporated into engineering classrooms.

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APPENDICES

Appendix A

Questions Included in Interview Protocol After Pilot Study

Question Category	Interview Questions
Self	What do you usually do during the summers?
	What do you do when you are not at school?
	What are your interests?
	What are your talents?
	If you had to write a story about your life, what would you put in it?
Family	What do your parents do for a living?
	What do your family members do when they are not working?
	What languages are spoken at home?
	Describe your household
	Do you have any chores you are responsible for?
	What else can you tell me about your family?
Community	What languages are used in your neighborhood?
	What is important to you about your community?
	How are you involved in your community?
	Have you lived in a community outside the United States?
	What differences have you noticed between communities?
	Can you think of ways your community can be improved?
School	What are you involved in at school?
	How many semesters were you in ESL classes?
	Can you think of any ways the school can be improved?
Workplace	Do you have a job? Tell me a little about it
	Describe a typical day at work
	What languages are spoken at your work?
	Can you think of problems people at your work are facing?

Appendix B

Protocol for Screening Interviews

- Are there any questions you have about the project right now?
- What grade level are you in?
- What extracurricular activities do you participate in?
- What do you typically do after school?
- How do you identify yourself (Hispanic, Puerto Rican, etc.)?
- Why do you identify yourself that way?
- What languages are spoken at home?
- Which language do you feel more comfortable speaking?
- Have you taken ESL courses?
- Do you have wireless access at home?
- What are good ways to reach you (texting, calling, emailing, Facebook messaging)?
- How long have you lived in the area?
- Do you know of people who want to participate in this project who you would like to work with?
- Do you know of people who want to participate in this project who you would not like to work with? We will not tell them you said their names.
- Do you have a preference of whether you work with boys or girls for this project?
- What math, science, and engineering courses have you taken?
- What kinds of things interest you?

- What are some problems that you see in your community, school, or home that need to be solved?

Appendix C

Protocol for Initial Individual Interviews

- Tell me a little about yourself.
- If somebody asked you to write a story about your life, what would you put in it?
- What are your interests?
- What are your talents?
- What are you passionate about?
- What do you like doing when you are not in school?
- What do you usually do during the summers?
- If you could do anything you wanted during the summer, what would it be?
- What do your parents/guardians/older siblings do for a living?
- What do your family members do when they are not working?
- What languages are spoken in your home?
- Please describe your household and yard.
- Can you think of any ways that the lives of your family, pets, or household could be improved through a physical or technological device?
- Do you have chores that you are responsible for? What are they?
- Are there jobs around your home that are challenging to do?
- Tell me a little about your friends.
- What do you like to do with your friends?
- How do you and your friends communicate with each other through technology?
- What languages do you use to communicate with friends? When?

- What do you think your friends think about engineering? Do your friends like building things?
- What social groups are you a part of (e.g., church groups, sports groups, etc.)?
- Can you think of any friends or anybody in these groups who could benefit from technological or physical innovations?
- Is there anything else that is important for me to know about your friends?
- Do you have a job? If so, please tell me a little about it.
- Please describe a typical day at your work.
- What languages are spoken at your work?
- Can you think of any problems that people at your work are facing? I am interested in hearing about problems that could be solved through improving the physical environment at your workplace or through suggesting ways that could make your work more efficient.
- Is there anything else that is important for me to know about your workplace?
- Do you help anyone do their work? (I am thinking of kids who help their dads, uncles, moms, aunts) What do you do? Are there ways that inventions or equipment could help?
- Tell me about your school.
- What are you involved in at school? (e.g., sports)
- What are your favorite classes? Least favorite classes?
- Have you taken ESL classes? What was that experience like?
- How many semesters were you in ESL classes?
- What do you think was the most beneficial thing about these classes?

- What bothered you the most about these classes?
- Can you think of any way the school building, grounds, or schedule could be improved?
- Is there anything else that is important for me to know about your school or about your experiences at school?
- Tell me a little about your community.
- Think about the ways people work and play in your neighborhood, are there changes that could be made or tools that could be developed that would make living in your neighborhood better?
- Is there anything that you know of that bothers your neighbors or the people in your community?
- Is there anything that you or people in your neighborhood would like to see changed?
- Is your neighborhood multilingual? What languages are used in your neighborhood?
- Is there anything else that is important for me to know about your neighborhood or community?
- In your opinion, what are some of the greatest problems that face our world today?
- Have you done anything to address those problems?
- What is your interest level in tackling those problems?

Appendix D

Protocol for Final Individual Interviews

- Overall, what were your thoughts on the engineering project?
- What was the most rewarding part about the project?
- What were you most proud of about the project?
- What were the most difficult parts about the project overall?
- Were you able to overcome those difficulties? If so, what helped you?
- What was particularly helpful to you throughout this project?
- What do you think you learned about engineering through participating in this project?
- On a scale from 1-10, what score would you give your final design and why?
- If you were to continue the project further, what would you do for next steps and why?
- What does the word 'engineering' mean to you?
- Please describe an engineer.
- Please describe what you think he/she does on a daily basis.
- What kinds of problems does he/she solve?
- Say that an engineer was given a problem to solve (name one of the problems listed above). How do you think he/she would go about solving that problem?
- Do you know any engineers?
- Have they ever talked to you about their jobs? What have they told you? What does this person do on a daily basis?

- Do you have any people in your family whose jobs might be considered close to engineering? Can you tell me more about that?
- What do you want to do for a job after you graduate from high school? Do you think that job is related to engineering in any way? Please explain your answer.
- Would you consider a career in engineering? Why or why not?
- What do you think your friends think of engineering?
- What skills or characteristics do you think good engineers have?

Appendix E

Protocol for Ongoing Individual Interviews

- Did you do any work on the engineering project any time between now and the last group meeting? Tell me more about it.
- Here is a list of search terms you used at the last group meeting to search for information. [Show list of search terms]. What you were thinking as you used these search terms?
- Did the search terms get you the information that you wanted? Please explain.
- Here is a list of websites (or apps) that you read at the last group meeting. [Show list of websites]. Why did you choose these websites over other websites?
- Were these websites helpful to you? If so, which ones were most helpful?
- Let's look at a helpful website and tell me what you got out of it? How do you think this information will help you with the project?
- Let's look at a website that you decided was unhelpful and tell me why you did not think it was helpful?
- Here is a sketch you drew of the design. Tell me about it
- What kinds of things were you considering as you drew this sketch?
- Have you had experience with making things like this sketch before?
- What was hard or easy about making this sketch? Please explain.
- Here is [another student product]. Will you please tell me about it?
- What kinds of things were you considering as you [made this product]?
- I noticed you said [repeat what participant said] while you were [making this product]. Will you please explain what you were thinking when you said that?

- Have you had experience with making things like [the participant’s product] before?
- What was hard or easy about making this [product]? Please explain.
- Anything else that has been difficult or challenging about this problem over the past several weeks? How did you address that difficulty?
- I noticed that you looked at this website. Will you tell me about your decision to do that?

Appendix F

Protocol Addressing Research Question Two

Question	Interview Questions
How are the participants' funds of knowledge used to address the self-selected community-based engineering design problem? (RQ2)	Can you explain this process in your own words?
	How do you choose whether to use Spanish or English when you are looking for information?
	What are you thinking about as you read this?
	Using your past experiences in [XXX], how can you investigate and solve this problem?
	What aspects of this problem do you know something about from personal experience?
	What would have happened if you didn't get that information from [XXX]?
	Has investigating the problem changed how you think about the problem?
	What do you think is the most important piece of data you have collected? Why?
	Describe an example of something you have learned at home that you used to solve the problem
	Describe how our conversations [meetings, interviews] have helped you work on the problem. What made it easier for you?
	In what ways does the problem remind you of any similar experience you have had? What parts are similar? How are they different?

CURRICULUM VITAE

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EDUCATION

2012 – 2014 Doctor of Philosophy in Engineering Education, Utah State University
Dissertation: "A Sociocultural Analysis of Latino High School Students' Funds of Knowledge and Implications for Culturally Responsive Engineering Education"
Adviser: Dr. Amy A. Wilson
GPA: 4.00

2009 – 2011 Master of Science in Metallurgical Engineering, The University of Utah
Thesis: "Characterization, Analysis and Simulation of Fine Coal Filtration"
Adviser: Dr. Jan D. Miller
GPA: 3.83

2003 – 2007 Bachelor of Science in Metallurgical and Materials Engineering
The University of Texas at El Paso
GPA: 3.80

FELLOWSHIPS & AWARDS

2014 The Institute on Teaching and Mentoring Scholar
2014 AERA Division G Graduate Students Mentoring Program
2013 Community for Advancing Discovery Research in Education (CADRE) Fellowship by the National Science Foundation – 2013-2014 Fellows
2013 Utah State University Graduate Research Symposium – Honorable Mention Research in Engineering
2007 Magna Cum Laude – The University of Texas at El Paso
2007 Alpha Sigma Mu Metallurgical Honor Society Scholar
2005 Tau Beta Pi Engineering National Honor Society
2003 Gates Millennium Scholar
2003 UTEP Presidential Excellence Scholarship
2003 League of United Latin American Citizens (LULAC) Scholarship
2003 Hispanic American Center for Economic Research (HACER) Scholarship

PUBLICATIONS

Huang, S., Mejia, J. A., Becker, K., & Neilson, A. (in review). High school physics: An interactive instructional approach that meets the Next Generation Science Standards. *Journal of STEM Education: Innovations and Research.*

Mejia, J. A., Goodridge, W., & Green, C. (2014). Using Web-based Learning Logs to Analyze Students Conceptual Understanding of Truss Analysis in an Engineering Statics Course. In Proceedings of the 2014 Frontiers in Education (FIE) Conference. Madrid, Spain.

Wilson, A., Mejia, J. A., Hasbum, I., & Householder, D. (in preparation). *Everyday Funds of Knowledge Relevant to Latino/a Adolescents' Engineering Design Activity*. Manuscript in review. Journal of Engineering Education.

Mejia, J. A., Wilson, A., Hasbum, I., & Householder, D. (2014). Funds of knowledge in Hispanic students' communities and households that enhance engineering design thinking. In *Proceedings of the 2014 American Society for Engineering Education (ASEE) Annual Conference*. Indianapolis, IN.

Mejia, J. A., Lin, C. L., & Miller, J. D. (2014). Fundamental aspects of fine coal filtration. In *Proceedings of the 2014 Society for Mining, Metallurgy and Exploration (SME) Annual Meeting and Exhibit*. Salt Lake City, UT.

Mejia, J. A, Goodridge, W., & Green, C. (2013). Enhancing engineering mechanics-statics instruction using manipulative truss models. In *Proceedings of the 2013 Frontiers in Education Conference*. Oklahoma City, OK.

Lin, C.L., Miller, J. D., Videla, A. R., & Mejia, J. A. (2010). Fine coal filtration as revealed by 3D Lattice-Boltzmann simulations. *International Journal of Coal Preparation and Utilization, 30,* pp. 217-238.

Lin, C. L., Miller, J. D., Videla, A. R., & Mejia, J. A. (2010). Fine coal filtration as revealed by 3D Lattice-Boltzmann simulations. In *Proceedings of the 2010 International Coal Preparation Congress 2010*. Littleton, CO, pp. 504-515.

CONFERENCE PAPERS AND POSTERS

Mejia, J. A., Goodridge, W., & Green, C. (2014). *Using Web-based Learning Logs to Analyze Students Conceptual Understanding of Truss Analysis in an Engineering Statics Course*. Paper presented at the 2014 Frontiers in Education (FIE) Conference. Madrid, Spain.

Mejia, J. A., & Wilson, A. (2014). *Community-based engineering design problems: Analyzing Latino students' linguistic, cultural and social resources.* Paper presented at the Society for Advancement of Hispanic/Chicanos and Native Americans in Science (SACNAS) National Conference, Los Angeles, CA.

Wilson, A., Hailey, C., Householder, D., & Mejia, J. A. (2014). *Community-based engineering design challenges for adolescent English learners*. Poster presented

at the National Science Foundation's Community for the Advancing Discovery Research in Education (CADRE) PI Conference, Washington, DC.

Wilson, A., Smithee, A, Mejia, J. A., & Hasbum, I. (2014). *Literacies in engineering: forms of capital used in immigrant youths' engineering designs.* Paper presented at the American Educational Research Association (AERA) Annual Meeting, Philadelphia, PA.

Mejia, J. A., Wilson, A., Hasbum, I., & Householder, D. (2014). *Funds of knowledge in Hispanic students' communities and households that enhance engineering design thinking*. Paper presented at the American Society for Engineering Education (ASEE) Annual Conference, Indianapolis, IN.

Mejia, J. A., Lin, C. L., & Miller, J. D.. (2014). *Fundamental aspects of fine coal filtration.* Paper presented at the Society for Mining, Metallurgy and Exploration (SME) Annual Meeting and Exhibit, Salt Lake City, UT.

Boyer-Thurgood, J. M., Tucker, S. I., Mejia, J. A., & Norman, P. (2014). *The socio-cultural importance of writing and sharing autoethnographic research.* Paper presented at the Hawaii International Conference in Education, Honolulu, HI.

Wilson, A., Mejia, J. A., Hasbum, I., Householder, D., & Hailey, C.. (2013). *Funds of knowledge and literacies in Latino/a youth's community-based engineering design work.* Paper presented at the Literacy Research Association (LRA) Annual Conference, Dallas, TX.

Mejia, J. A., Goodridge, W., & Green, C.. (2013). *Enhancing engineering mechanics-statics instruction using manipulative truss models.* Paper presented at the Frontiers in Education (FIE) Conference, Oklahoma City, OK.

Mejia, J. A. (2013). *Examining Latino students' linguistic and cultural resources when addressing engineering design activities.* Poster presented at the American Society of Engineering Education (ASEE) Annual Conference, Atlanta, GA.

Mejia, J. A. (2013). *A loss to explain: Identity.* Paper presented at the Utah State University Graduate Research Symposium, Logan, UT.

Lin, C. L., Miller, J. D., Videla, A. R., & Mejia, J. A. (2010). *Fundamental analysis and simulation of fine coal filtration.* Paper presented at the Society for Mining, Metallurgy and Exploration (SME) Annual Meeting and Exhibit, Phoenix, AZ.

RESEARCH EXPERIENCE

2014 *University of Washington, Pioneer Interviewer*
Conducted interviews and created profiles of engineering education pioneers for the Center for Engineering Learning and Teaching (CELT) at the University of Washington (Project funded by NSF). The interviews were done via Skype and the audio files were transcribed and used to draft a profile of the engineering education pioneer. The objective of the project was to document and analyze the participants' contributions, influence, challenges, and successes in engineering education.

2012 - 2015 *Utah State University, Graduate Research Assistant*
Conducted research on community-based engineering design challenges involving Latino students in grades 9-12 (DRK-12 Project funded by NSF). This work included the use of an ethnographic approach to qualitative research. The objective of this research was to develop a framework of funds of knowledge and engineering-related funds of knowledge that instructors can use to provide culturally responsive engineering education.
Designed and led research on the use of physical manipulatives in basic engineering courses.
Conduct research on misconceptions in physics education and methods to improve understanding of difficult concepts in physics using engineering design processes.

2009 - 2011 *The University of Utah, Graduate Research Assistant*
Research involved fine coal filtration and dewatering in filtration cakes. The study implicated the use of Lattice-Boltzmann simulations and X-ray micro computed tomography to determine pore network structure and generate a model that describes the conditions for improved water removal during filtration.

2008 - 2009 *The University of Oklahoma, Graduate Research Assistant*
Research involved the use polymers in the fabrication of nanoparticles for drug delivery systems.
Encapsulation of hydroxyapatite on PLGA-based nanoparticles to enhance osseointegration of titanium dental implants. The nanoparticles were obtained through a double emulsion method and characterized using zeta potential, transmission electron microscopy (TEM) and scanning electron microscopy (SEM).
Conducted studies on the controlled release rate of encapsulated hydroxyapatite nanoparticles using high performance liquid chromatography (HPLC).

TEACHING EXPERIENCE

2012 - 2014 *Utah State University, Teacher Assistant*
Tutor students, teach laboratories and recitation sessions, proctor exams, grading, and conduct research for ENGR 2010 (Statics).
Developed physical manipulatives of trusses for instruction of difficult concepts in statics.

2013 *Johns Hopkins University, Teacher Assistant*
Innovations in Engineering at the Center for Talented Youth Program at the Johns Hopkins University. Tutored students, taught laboratories, created activities for students, developed lectures and updated curriculum,

proctored exams, graded tests and homework, and worked on different activities with students ages 14 to 17.

2010 - 2011 *The University of Utah, Teacher Assistant*
Prepared assignments for the students, graded papers, conducted lab experiments, and taught the laboratory section for the Minerals Processing II course.
Class included undergraduate and graduate students from the Mines and Earth Science College at the University of Utah.

2005 - 2007 *The University of Texas at El Paso, Team Leader/Peer Tutor*
Organized and administered team-building activities and prepared orientations for new employees.
Worked assisting student in a wide variety of college courses including physics, mathematics, and lower-division engineering classes.
Provided reviews for the Basic Engineering Exam for undergraduate students. Results showed an increase in passing students who could enroll in upper division classes.
Proposed a series of review seminars for senior students taking the Fundamentals of Engineering Exam as a step forward to help students obtain Engineer in Training (EIT) licensure.

PROFESSIONAL EXPERIENCE

2011 - 2013 *FLSmidth Minerals, Project Engineer*
Worked on different operations and maintenance contracts for mining companies in different countries including Mexico, Peru, Chile, South Africa, Zambia, Denmark, Canada, and the United States.
Provided technical services to the client involved in the different contracts, such as flotation and recovery of minerals, grinding circuits, filtration and mineral analysis.
Created and conducted the "Mineral Processing of Copper" introductory training program for FLSmidth employees. Training course included the processing, characterization, mining and recovery of copper silicates and copper oxides targeting the main aspects of copper processing (blasting, comminution, separation, electrowinning, electrorefining, smelting, etc.).
Created a safety program for FLSmidth personnel in Zambia, which resulted in good improvements and the decrease of lost time injuries and near-miss incidents.
Worked on vacuum and pressure filtration tests of different minerals and soils and determined the final moisture content of the cakes.

2010 *Rio Tinto, Graduate Intern – Technical Services*
Process improvement for the recovery of copper and molybdenite (flotation experiments).

Analysis and preparation of mineral assays to determine recovery, grade, and quality of minerals.

2007 - 2009 *Tinker Air Force Base, Materials Engineer*
Participated in the failure analysis and first article qualification investigations performed in the Metallurgical Analysis Laboratory.
Involved in the process of quality evaluations including materials testing, thermal spray coating quality control and the continuous efforts to improve process methods for the thermal spray section (Aerospace Metallography and Coating Evaluations Certification).
Provided engineering support for preproduction planning regarding materials application, selection, and processing. Determined appropriate corrective actions while considering technical variables, risk, quality, and production factors.
Involved in the jet engine mishap investigations and coating evaluations of plasma sprayed parts.
Participated in the writing of proposals for the purchase of equipment needed for the use of the laboratory, including grinding and polishing machines, mechanical convection ovens, mounting presses, and hardness testers.
Worked with NADCAP, ASTM, SAE, and military standards for material evaluation and testing. Knowledge of OSHA, HAZMAT and ISO 9000.

2005 *Raytheon Missile Systems, Tech-Student Engineer Intern*
Designed a series of prototypes of launchers focusing on expenditures, functionality and material performance for future use and testing.
Worked as assistant in the stereolithography laboratory.

SERVICE

2012 - 2014	Conference paper reviewer, American Society for Engineering Education Annual Conference and Exposition
2014	MESA arm contest judge, Granite School District MESA Day
2013 - 2014	Conference paper reviewer, Frontiers in Education Conference
2013 - 2014	Workshop facilitator, Noche de Ciencia (SHPE)
2013 - 2014	MESA arm contest judge, USU Physics day at Lagoon
2013 - 2014	Mentor, Utah State University MESA-STEP Scholars
2013	Science fair judge, Bridgerland Science and Engineering Fair
2012	Workshop facilitator, NASA Space Science Day at Utah State University
2005 - 2007	Workshop facilitator, Science Extravaganza for Middle School Youth
2004 - 2013	Gates Millennium Scholarship Mentor, Gates Millennium Scholars

SKILLS AND CERTIFICATIONS

Bilingual: Fluent in English and Spanish
Engineer in Training (EIT) by the Texas Board of Professional Engineers
NVivo software for qualitative data analysis
SPSS software for quantitative data analysis
Jet Engine Mishap Investigation Certification
Aerospace Metallography and Coating Evaluations Certification
Fatigue, Fracture Mechanics and Damage Tolerance of Aging and Modern Aircraft Structures Certification
Knowledge of XRD, SEM, metallography, hardness testing, impact testing, tensile testing, and heat treatment
Proficient in MS Word, Excel, Power Point, and Outlook, Solid Works and Minitab

PROFESSIONAL MEMBERSHIPS

American Educational Research Association (AERA)
Society for the Advancement of Chicanos and Native Americans in Science (SACNAS)
Literacy Research Association (LRA)
American Society for Engineering Education (ASEE)
Society of Hispanic Professional Engineers (SHPE) - USU SHPE Chapter Graduate Representative (2012)
Society of Mexican American Engineers and Scientists (MAES)
Tau Beta Pi Engineering National Honor Society
Society for Mining, Metallurgy, and Exploration (SME)
The Minerals, Metals and Materials Society (TMS)