Funds of Knowledge in Hispanic Students' Communities and Households that Enhance Engineering Design Thinking

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Abstract

Although there has been a growing body of research addressing how teachers may draw from students' funds of knowledge in science and mathematics, very little research has been conducted on how the funds of knowledge of Latino students may enhance engineering design thinking. The purpose of this study was to document the funds of knowledge of three Latino adolescents as they worked on a community-based engineering design problem. We sought to identify how the adolescents' values, interests, workplace skills, language skills, experience with household maintenance, and other funds of knowledge were used in ways that enhanced their engineering design thinking. The findings suggest that Hispanic students bring rich funds of knowledge that can be used to augment engineering design thinking and activity. By identifying these categories of funds of knowledge, we hope to move toward the creation of culturally responsive high school engineering instruction that actively seeks to connect Hispanic students' out-of-school practices to the formal practices of engineering.

Introduction

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,[1] research indicates that careers in engineering and science are dominated by individuals whose background is White, English-speaking, and middle class.[2] Even though the Latino population is expected to increase and continue to influence the labor force of the country, there are no studies indicating that the number of Latinos in either science or engineering will likewise increase.

Many scholars have offered similar explanations for this phenomenon.[3-5] For instance, Johnson, Brown, Carlone, and Cuevas described women of color who were actively discouraged from pursuing college degrees in STEM fields because people believed they would not succeed, [6] a finding that was echoed by Rochin and Mello who similarly concluded that many in academic and professional settings hold "the general perception that Latinos cannot advance through the [STEM] pipeline" (p. 306). [7]

Other scholars explain the underrepresentation of Latinos in engineering by asserting that "cultures of engineering" seem foreign to many Latino students' home cultures. [8] In other words, Latino students often do not see connections between engineering practices and their own personal interests, values, languages, household bodies of knowledge, and social or cultural practices. Indeed, Aikenhead and Jegede described underrepresented students' transitions between their home cultures and STEM classrooms as a type of "cultural border crossing," a metaphor that suggests a "student's life-world and school science" are two distinctly bounded, separate entities (p. 269). [9]

To counter this disconnection between Latino students' everyday lives and the instruction they receive in their STEM classrooms, the National Research Council indicated that STEM instruction "needs to connect with students' own interests and experiences" (p. 2-4).[10] While a growing body of research has begun to address how teachers might draw from adolescents' diverse cultural resources, linguistic resources, and community concerns in science [11, 12] and mathematics, [13,14] very little research has been conducted on how the same task might be accomplished with Latino adolescents in the field of engineering.

Therefore, the purpose of this exploratory case study was to investigate the funds of knowledge that one group of Hispanic students used as they tried to solve a problem in their communities through engineering design processes. By identifying continuities between Latino adolescents' everyday lives and engineering, we hoped to identify ways that high school engineering teachers could make their instruction more responsive to the cultures of Latino students and less like a "cultural border crossing." [9]

In other words, this study was 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 students to enter and remain in the field of engineering. However, in order to build this bridge, the research and education community first needs a framework outlining funds of knowledge that are relevant to engineering design. Accordingly, the purpose of this exploratory study was to begin to describe the funds of knowledge from which high school engineering teachers might draw as they seek to provide culturally responsive engineering instruction to their Latino students. In the following sections, we outline a socially-situated view of engineering design processes and explain how funds of knowledge relate to that view.

A Sociocultural View of Engineering Design Processes

Dym and colleagues described design as "a systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints" (p. 104). [15] Although there are different descriptions of the design process, [16, 17] most of the models of engineering design are viewed as largely cognitive and tend to focus on relatively uniform frameworks for thinking and "habits of mind." This line of research has led to claims that certain types of cognitive activity over a particular duration of time can lead to better designs. [16, 18]

However, we do not view engineering design as a strictly cognitive activity that is separate from relationships, material worlds, cultures, and everyday experiences. Instead, we view engineering as a type of Discourse, which Gee has 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 with various objects, tools, and technologies, so as to enact specific socially recognizable identities engaged in socially recognizable activities (p. 155)* [19]

In accordance with this definition, we conceptualize engineering design processes as the enactment of a larger engineering Discourse. Godfrey and Parker described this Discourse as including "the Engineering Way of Thinking" and the "Engineering Way of Doing" among people who practice "Being an Engineer" (p. 8). [20] These people are recognized as 'one of us' by other engineers who deem their "physical, tangible Artifacts and visible behaviors" to align with the norms of engineering (p. 8).

Depending on their experiences at home and with their peers, some adolescents may acquire ways of thinking, doing, valuing, communicating, and using particular sets of tools that somewhat align with engineering. Theoretically, they would be more likely to develop identities as engineers as compared to adolescents whose cultural worldviews, values, tools, and practices did not cohere with Discourses of engineering. These latter students, therefore, would benefit from engineering instruction that values their out-of-school practices and uses them as a bridge to the formal practices of engineering so that students do not feel like engineering is a "foreign" discipline that is "not me." [21]

Theoretical Perspectives of Funds of Knowledge

In previous educational literature, the construct of "funds of knowledge" has served as a bridge that connects students' household and peer bodies of knowledge with the formal bodies of knowledge learned in school. Authors have used the term "funds of knowledge" to describe the cultural knowledge and skills present in students' households and communities, which include knowledge related to agriculture, health, workplace skills, ethics, financial management, and marketing. [22, 23, 24]

Gonzalez et al. performed a series of ethnographic and anthropologic studies with a group of students in Southwestern USA. [25] Their work documented different funds of knowledge based on students' life experience, thick social networks, and family survival strategies. These funds of knowledge were built through relationships in systems of exchanges. For instance, one family in the neighborhood might have a son with experience in reading and interpreting legal documents, who could help another family with immigration papers, while another family could include car mechanics who helped their neighbors repair broken cars, and so forth. These systems of exchange are conducted within the context of "confianza" (trust). Moll et al. similarly found that "social relationships facilitate the development and exchange of resources, including knowledge, skills, and labor, that enhance the households' ability to survive or thrive" (p. 133). [23] Thus, students' funds of knowledge are formed not only through cognitive activity but also as part of social interactions.

Previous studies have suggested that, when these funds of knowledge are incorporated into science curricula, students are more engaged and often develop richer understandings of scientific concepts. For example, Barton and Tan [22] and Moje et al. [12] demonstrated that underrepresented students' experiences with work outside of the home, with work inside of the home, with popular culture, with health (e.g., managing diets), with international travel, and with the environment were all generative platforms on which to base engaging, socially relevant science instruction. We hoped that, by extension, Hispanic students' funds of knowledge could serve as a platform from which high school engineering teachers would provide more engaging, culturally relevant engineering instruction. As in these previous studies, we assumed that teachers who incorporate Hispanic students' funds of knowledge would bridge Discourses of engineering with students' everyday Discourses.

Research Question

To our knowledge, no studies have conducted on how the rich funds of knowledge in Latino communities can be connected to engineering design. Therefore, we developed an in-depth ethnographic study of Latino high school students in which we documented how informal resources, such as their funds of knowledge, seemed to contribute to more formal engineering design activities. Specifically, we asked the following research question: How do Latino high school students use funds of knowledge as they work toward implementing a community-based engineering design activity? Guided by this question, we present an analysis of the funds of knowledge used by three Latino high school students as they worked on a community-based engineering design activity.

Context of the Study

Throughout the course of one school year (nine months), we followed a group of 10 Latino adolescents (ages 14-17). We used two venues to introduce the research project to Latino/a students and ask for volunteers: the local MESA (Mathematics, Engineering, and Science Achievement) clubs and LIA (Latinos in Action) clubs. Preference was given to Latino students who spoke Spanish at home and who had recently received or were currently receiving English as a second language services in their schools.

The students were divided into three different groups. Each group selected a problem in their community that was of interest to them. 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, tried to improve an existing device for restraining cats before they get vaccinated in veterinary clinics. The third group, consisting of three boys, worked on designing a wheelchair-accessible door for students with disabilities at their high school. Each group met twice per month in local community locations of their choosing and together we (the researchers and students) visited their workplaces, local parks, and other community locations that were relevant to the problem that they had selected. In addition, each participant received an iPad and engineering notebooks throughout the duration of the study.

This paper describes the findings from the third group. We decided to focus on this group because the findings from this group (e.g., the codes we assigned to the data) were representative of the whole data set. The group selected for analysis serves as a telling case, which represents "identical general theoretical principles" similar to those exhibited by the other groups (p.192). [26] The telling case allows for a "detailed examination of an event" that functions to "stimulate generalizations and induce theoretical interpretations about contextual circumstances" (p. 295). [27] By focusing on this group, we hoped to provide a "thicker description" of each group member than would have been possible than if we had described all ten students.

Method

Data sources included individual interviews, observations of group discussions, and student products. We conducted an initial and final interview, in addition to monthly interviews, with each individual research participant in order to establish a relationship between the students and the researchers and build a certain level of "confianza," or trust. The initial interviews were no longer than one hour and students were asked questions about their background, family, school, work, friends, households, and neighborhoods. In the monthly interviews, we asked questions to further determine the funds of knowledge that students used to address the engineering problems. For instance, when Miguel mentioned a hydraulic lift at his workplace while he was talking during one of the group meetings, we used his comment as a basis for further questions about what he knew about the hydraulic lift at work and how that knowledge might help his group with the engineering problem they had selected. In other words, all questions asked during these meetings were open-ended questions intended to elicit information about their funds of knowledge, social networks, and engineering design processes.

In addition to collecting individual interviews, we observed the group meetings, which were held about once every three weeks, in which the group members identified a problem in their community that needed to be addressed, and then discussed how they would address that problem. These group meetings were facilitated by two of the researchers whose background is in engineering. The researchers' role during these meetings was to ask open-ended questions to prompt discussion if the students seemed unsure of what to do next. For instance, we often said things like, "Last time, Francisco had suggested that you do [XXX] and Miguel had suggested that you do [XXX]. What do you think of those ideas?" We read transcripts of previous group meetings in order to create protocols for upcoming group meetings. All meetings were recorded using audio and/or video sources.

Finally, we collected products generated by the research participants, such as drawings they produced of their designs and records of the websites they visited during the information gathering stage of the design process. We gave the participants an I-pad throughout the course of the study so they could conduct additional research or record their design ideas at home, and we used these student-generated products as the topic of interview questions. There was no restriction on the number of webpages they could use or the applications they could download and use to work on the problem.

A modified version of constant comparative analysis was used to analyze the data. [28] Our version of constant comparative analysis was shaped by previous research connecting adolescents' everyday Discourses to science Discourses. [12, 22] The whole data set was later analyzed while mutually agreeing on each code. [29] For instance, codes related to funds of knowledge included: parents' occupation; students' experiences at their workplaces, household maintenance, popular media, and video games.

Below, we divide the findings into two sections. The first section describes the funds of knowledge used by each individual research participant, while the second section describes the funds of knowledge used at each stage of the engineering design process.

Findings: Accumulated Funds of Knowledge

The three participants exhibited different funds of knowledge that shaped their everyday Discourses. They described their family networks, life experiences, and work experiences that influenced their everyday learning. In what follows, we present descriptions of the three Latino students participating in this study and the funds of knowledge that each of them brought to bear on the project.

Francisco: Collective Learning

Francisco was a senior at his high school and he immigrated to the United States at a young age. Like Francisco, the first author was raised in the same city located on the U.S.-Mexico border. This commonality created a strong relationship that was characterized by confianza. Learning from his parents became one of the main topics of discussion. Francisco indicated how he learned from observation and direct instruction from his parents, especially his dad. Francisco mentioned that fixing cars with his father helped him develop an interest for electronics as he said,

> *We fix [the cars] but we learn together. We'll get on the computer and research for a little bit and watch a YouTube video, then go outside and we fix it. So we learn at the same time and we work together.*

Francisco's dad was an industrial engineer in Mexico, as well as a supervisor at a *maquiladora* on the United States–Mexico border. He exposed Francisco to different experiences not only related to mechanical engineering, but also to how to take care of a farm. Funds of knowledge relating to farming were transferred through generations in his family:

> *My dad used to work, well, he remembers from his dad. He used to live in a rancho (farm) in Mexico so he remembers that stuff. On the side yard my dad has a garden and in Spanish he calls it "jardín." My family loves chili, so we grow the green chili, jalapeño, California, also tomatoes, squash, cucumbers, and corn.*

Francisco applied this knowledge of farming at the dairy farm where he worked and has applied what he has learned on his own garden when he mentioned how he planted corn "strategically" in order to protect other plants from incoming gust. These funds of knowledge gave Francisco a wealth of knowledge related to the environment, including the importance of building designs that do not accelerate erosion or harm physical surroundings.

Francisco also talked about his social networks and how these have influenced his life. He was involved in Latinos in Action and Boy Scouts, where he had been able to connect with different leaders in the community. He described how his interactions with different people had made a positive impact in his life:

> *I think it's about the connections because I'm not going to the university yet, and they already know who I am. So if I need something I can call them, email them, and they will let me know about different things I can try to go to college, so it's already like my network.*

Francisco also indicated that trust was a very important aspect of building relationships. Most importantly, he mentioned how he was able to build relationships with those teachers that "really care about how you are doing." Through these relationships, he was able to get jobs at a dairy farm and a chicken farm. Francisco had been working at a dairy farm for several months at the time of our interviews. He impressed us with the knowledge he gained at the dairy farm, such as the effects that bacteria have on cows, how the cows can get infected with mastitis, how to test for mastitis, how to care for the animals, and how to properly operate the machinery at the dairy farm.

He knew from work that sometimes the *optimal* solution may not be the *ideal* solution and that there are always trade-offs when working on different projects. For instance, he stated that one possible *ideal* solution for reducing bacteria in the cow's milk would have been to buy a device that would indicate early whether a cow had mastitis, so the cow's infected milk would not have been poured into the overall milk supply. However, his boss could not afford the device, so they had to rely on less expensive means (and less reliable means) of detecting mastitis. From this experience, he learned that reducing costs had its advantages (his boss could save money) but also its disadvantages (some high-bacteria milk from sick cows got into the milk supply).

Francisco demonstrated a wide variety of funds of knowledge through his life and work experiences, household, and social networks. The importance of these social networks and learning from others is also an important part of engineering, where teamwork is encouraged and necessary to work on engineering design problems. Thus, although the connection between everyday Discourses and engineering Discourses may not be immediately evident to engineering teachers, it exists.

Miguel: Building Relationships

Like Francisco, Miguel was raised on the U.S.- Mexico border and he moved to the United States at a young age. In fact, Francisco and Miguel's families had known each other for several years. They lived in the same city and it was Francisco's dad who convinced Miguel's family to come to live in the same community. It was through this relationship that Francisco and Miguel became close friends and were able to get jobs at the same dairy farm. The knowledge gained through his job at the dairy farm was impressive. Like Francisco, Miguel could describe how the presence of large numbers of bacteria affects the processing of the milk. He stated:

> *The milk that they use from these farms I think they use it for yogurt, they don't use it for milk. If it's over 400,000, they won't take that milk. So they go to make powdered milk for the baby calves. You can minimize [the bacteria] but you cannot completely eradicate it.*

He described how the amount of "somatic cells" in the milk must be kept to a minimum of 200,000 in order to have a good product. In addition, he described how working in the farm has helped him learn more about the animals and being able to detect when they are sick, feed them, and nurture them. His description shows how the adolescent was able to learn from informal resources (farm and work colleagues) and was aware of the different constraints when allocating money or resources to different projects. The economic factors, decisions, and solutions played an important role when trying to find the optimal solution to a problem presented by his boss. This argument resonates with engineering design and how different factors must be taken into consideration before a decision is made.

Miguel also mentioned the importance of learning from his parents, relating to Francisco's description of his *jardín*. Miguel's family "grows tomatoes, jalapenos, lettuce, and potatoes." Additionally, Miguel has learned how to work on different machinery learning from his dad:

> *My dad works on a farm. He fixes the tractors and he works with the tractors to combine the grain. They combine the grains and stuff to feed the animals. I helped him take the transmission so that he could fix [the part] because you have to take the transmission to be able to get it [to work]. He would tell me to give him the tools or take the screws off and what to take off.*

These valuable experiences helped Miguel create very strong funds of knowledge that helped him in school. He indicated that he became involved in an agriculture class and a robotics competition where he was able to transfer the knowledge gained from his job and working with his parents.

Moreover, Miguel was also involved in Boy Scouts and Latinos in Action, where was involved in community service projects, developed thick social networks with his peers and with the community, and learned different survival skills such as fishing, cooking, making a tent, and making a fire. In this regard, his interactions with others and his past life experiences increased his desire to collaborate with others in order to improve the community. His knowledge shows an understanding of societal, environmental, technical, and other factors that are essential in understanding engineering and engineering design in a holistic way.

Eduardo: Helping Others

Eduardo was the only participant who was born and raised in the United States in a combined Mexican and American culture. Like Francisco and Miguel, Eduardo was involved in Latinos in Action and Boy Scouts, where he had been able to connect with different leaders in the community. Eduardo observed how these interactions created a positive impact in his life:

> *Since my dad is a representative [of our church], I've got to go around all the different wards [church congregations] and different member's houses. Because of that I have been able to do a lot in the Hispanic community. I am able to interact with both the Americans and Hispanics a lot easier going back and forth between the two of them.*

Eduardo mentioned how his interactions with his dad helped him become more involved in the community. Through his dad, he learned how to work on construction projects by remodeling their house, and he helped other members of the community on such projects. Although Eduardo was not exposed to the same type of farm labor that Miguel and Francisco were, he was familiar with some of the work performed on the farm since his family owned a farm. He had been actively engaged in different activities on his farm such as feeding the animals and helping repair fences.

However, Eduardo's story is different in many aspects compared to Miguel and Francisco's story. Eduardo was not very fluent in Spanish and he described his household as "more

American." His dad was from Mexico and his immediate family still lived there at the time of our conversations. He had been to his dad's hometown only once when he was in third grade. Nonetheless, it was interesting to see how Eduardo built thick social networks through his dad and his influence on the Hispanic community through the church:

> *I guess the common thing is whenever we go to different [houses] they're always receptive; they're really appreciative of what they're getting. We need to at least put a little bit of time you know visiting with our friends and making sure that they're being alright, like they're alright since we know them really good you can forget them for a while because you know how they've been and they'll probably be fine.*

These church visits and his Latinos in Action activities was the only connection he had with what he called the "Hispanic culture." Nevertheless, Eduardo, like Miguel and Francisco, learned many skills from his parents. He explained how he learned not only social skills from his dad but also how to work in the farm:

> *My dad, he got sick for a little bit like for about a week and he was off work for a week so then I helped him out for a couple days like he told me the first day what they need to do with the hay which is mostly he had the two different types of hay, like hay and straw.*

He emphasized his interest in helping other people, improving people's lives, serving mankind, and "being an example" to others. Eduardo was a well-educated young man with different interests such as reading, helping others, and collaborating with his community. Likewise, several engineers mention empathy as an important part of the design process since they must meet the needs of those in different circumstances.

In sum, across all three participants, social relationships enabled students to connect with those who provided knowledge in their environments. These interactions with the community were part of the social interdependency observed throughout the interviews and group discussions with the students. The students mentioned the importance of the "rewards" obtained from these relationships with members of their communities. Also, the importance of trust became a focus on their discussions regarding the relationships created with members of the community.

Funds of Knowledge Used at Each Stage of the Engineering Design Process

This section describes the participants' approach to selecting and working on the community-based project. It includes the different components of the engineering design process such as: (a) identifying the need or problem, (b) developing possible solutions, and (c) selecting the best possible solution. This project focused on the use of funds of knowledge of the students and not on the finalized engineering artifact or final product.

Identifying the Need or Problem

The participants used their experiences in diverse school organizations different topics were brought up to our attention. The brainstorming stage included a variety of ideas that could have been used as their community-based project. For example, they relied on their previous knowledge regarding the work Francisco and Miguel performed at the dairy farm and tried to develop a plan to decrease the number of bacteria accumulated in the milk tanks at the farm. Through their observations, they identified different problems in the milking process, which could have prevented the high levels of bacteria in the milk such as: cleaning the udders with the appropriate method, changing and cleaning tubing when necessary, in-situ testing for mastitis, changing tank filters, proper training of employees, identification of sick cows, maintenance of the equipment, and proper temperature and pressure on the tanks to eliminate bacteria.

Although this theme was of high interest to the students, they finally decided to focus on problems that would eventually help students with disabilities at their high school. Their perception of engineering was centered on the benefit and well-being of others. Eduardo mentioned the importance of continuous improvement dedicated to the well being of the community:

> *Improving what I guess the current procedures for say technology or whatever is already out there, just continuing improving things and kind of new ideas and improve let's say everybody's way of life.*

From their previous experience working with the students with special needs, the students decided that working with students with disabilities would not only solve a problem in the community, but also help the student to have a sense of independence. One of the major themes was creating automatic doors that would reduce the problems many students with disabilities faced at their high school. Their first observation was the need for automatic doors due to the several limitations in the current design at their high school. Francisco mentioned that it would benefit students because it was extremely complicated for them to go to classrooms in other buildings without automatic doors. The layout and design of the doors at the high school had posed some constraints for the students with disabilities, since there were two sets of doors and limited space to help the students get through the doors. Miguel indicated that:

> *When the mentors help the students, it is really hard to get through the door. You have to open one set of doors, and then you close that and you have to go back to the next door. So I was wondering if there is a way we could make doors that open automatically or see if there's a different way to possibly open the doors. So I wouldn't say throughout the entire school, but at least for that little section right there, because that's where their classroom is.*

Their observations included not only the needs to address the problem, but also there was a concern about the well-being of the students with disabilities, and they determined that this could be implemented in many other situations. Their intrinsic motivation appeared to be the need students observed with the group of people they had worked with before. All three students were involved in service projects where they helped and worked with students with disabilities. The project required participation, hands-on experience, knowledge, skills, and it was challenging. Most importantly, the students envisioned how the application of this project would eventually improve the quality of life of the people with special needs. Thus, the project involved not only applying scientific knowledge, but also the consideration of engineering ethics, practicality, safety, cost, and dissemination for further applications.

Developing Possible Solutions

During the discussions, the students were given iPads and engineering notebooks to work on the project. The students used the notebooks to create different drawings, illustrating the layout of the doors at the high school. Francisco explained why the graphics were important when communicating the product to others. He indicated that it was difficult to communicate ideas verbally and sometimes it was necessary to make sketches that would illustrate ideas in a less complicated way.

They approached the problem by first identifying different options that would solve the problem. Different solutions were brought to the discussion: a sensor, a solar panel to provide energy, electrical power, and hydraulics. The students also indicated the different constraints in this project such as: the cost, materials, energy, possible mechanisms of operation, and maintenance. After discussing the different solutions, Francisco provided some guidance to the group by indicating that the first step should be to decide what they should do and "just go from there so we're not like all over the place." One of the major concerns for the students was how to make the doors open and close automatically and in a systematic way that would allow for better "traffic" of students through the doors. Miguel mentioned the possibility of using a hydraulic system to open and close the doors similar to a mechanism he observed at the dairy farm:

> *Yeah, well, at work, you know, they have the hydraulics. It's a huge [bar] as big as this room but it is long and just with the hydraulics it brings it up and then it brings it down. It's like this big and it just comes up and the cows come out and then they press the button again and it comes down.*

They were able to identify similarities between different mechanisms that could have the same application under different conditions. The idea of opening and closing the doors using hydraulics seemed to be a reasonable solution; however, they were able to identify different constraints pertaining to the hydraulics system such as: the size of the system, the weight of the doors, and the cost. Francisco indicated some of his main concerns with the hydraulics system, but emphasized the importance of creating a plan and research on the topic due to the differences in applications. He identified different constraints that could have been detrimental when solving the problem. Some of his concerns included the effects of outside temperature on the hydraulics system, the amount of energy required to operate the system, and the size of the hydraulic pumps among others. Another major concern for the students was how to make the doors open and close automatically but making it more accessible to the students with disabilities. Several alternatives were mentioned, including the use of magnetic cards due to their convenient use and low maintenance costs for the school. They described the different approaches to these problems:

> Eduardo: *Like list the different parts that we'll need to use like say the button, how we're gonna open the door, different stuff like that.*
> Miguel: *Like look at the sensors, for example. What type of sensor would work better for or, you know, like the -- yeah, like if there's different types of key cards or, you know, device.*

> Francisco: *Previous models and see how they work and maybe from there get an idea of similar things we could use, as well as adding new technology into it like the stuff we're gonna add to it.*

The students also mentioned asking experts who could explain the different mechanisms that could work. Also, they indicated that researching online was a very good tool to use for the project. Francisco mentioned that using search engines, forums, and warehouse websites would give them the information they needed to work on the project, including specifications that must be taken into consideration.

Selecting the Best Solution

The next step in their design process was to decide whether the doors would open simultaneously, or not. One of the reasons they determined this was important was the traffic of students in the hallway. If the doors were not opened simultaneously, the amount of students trying to pass through the doors every class period would block the passage for the students with disabilities. They reached a conclusion to have the doors open simultaneously and simulate the traffic like cars on a highway. The doors on the right would open simultaneously to let students pass through the doors as they walk toward the outside, while the doors on the left would open simultaneously only for the people going inside the building. The doors would be opened and closed independently from each other but would allow for a faster traffic of students between class periods.

Discussion

The funds of knowledge found in this study were not as anticipated by the research team. Although the students had the access to different sources of information, including iPads, internet, and the expertise of two engineers, the students relied on "word of mouth" from parents and other family members, or parents' experience. However, this information was valuable and used to create a protocol to help Latino students become aware of alternative sources of knowledge.

It is also important to mention that the students struggled to move along the engineering design cycle. Students spent a long time in the brainstorming stage and had different challenges defining the problem. Although it was the intention of this project to let students frame the problems they were interested in, it took a lot of effort to get the students to identify the community-based engineering design problem and move past the brainstorming stage. Even though each group offered a solution to problem, this paper does not suggest that their final solutions approximated the solutions of professional engineers in terms of overall quality. The takeaway message is that helping the students find and define the problem was more difficult than expected. Nonetheless, the results obtained from this study provide an insight into the interests and funds of knowledge of Latino students in an effort to give Latino students empowerment, and outline the kinds of outreach necessary to increase the interest and the number of Latinos in engineering.

The narratives described here are just a few examples of how Miguel, Francisco, and Eduardo created a network of people that provided a support system for them. The students also showed different funds of knowledge gained through different work, household, and life experiences. These life experiences show how the students gained understanding of their environments through observations, learning from other peers, and personal discovery. Moreover, different topics were identified by the students as pertinent to engineering such as observations, optimization, testing, standardization, and systems thinking. In addition, the three students were able to engage in practices that became significantly important when working on the community-based engineering project.

Miguel, Francisco, and Eduardo were able to make different connections between their funds of knowledge and their classroom knowledge. According to Moje et al., [12] funds of knowledge shape the ways of knowing, also called Discourses, and how the students bring these funds of knowledge to the classroom where it is combined with "classroom knowledge," especially science knowledge. One work experience that became important in our discussion was their knowledge about farming and the dairy industry. Francisco was able to make a connection between the use of hydraulics systems in a tractor and the restraining bar at the dairy farm, and how it could create different constraints to the doors if this system was used. He indicated that the amount of pressure created by the pump was related to the force required to activate the mechanism:

> *I work with tractors, it is similar and there needs to be so much pressure for it to work. I know they have the pump and on the dairy we have those doors, we have a back room where there's a square machine that makes the pump activate so when we press that button it actually pumps hydraulic fluid. So it pushes the hydraulic fluid and makes the arm expand because it's creating force into the arm and it is making the door open.*

This merging of practices and ways of thinking makes Francisco's engineering habits of mind remarkable and significant for the project. He was able to foster a new understanding where household knowledge emerges as a significant contribution to the project by connecting it to engineering design thinking. Miguel, who was involved in a robotics team described the use of hydraulics used in robotics, was also able to fully understand the mechanism used in hydraulics and how this could be beneficial to the project. Integrating "classroom knowledge" and knowledge from the farm, he indicated how some of the concepts he knew could be applied to the project:

> *On the robotics they had a robot but it worked just with hydraulics and the hand would move up, then grab a pencil and I just think that with the door you're kind of doing the motion just like that. So, you know, I was just thinking if maybe, and they would program it so we could maybe do the same thing.*

This integration of knowledge and Discourses drawn from different spaces (household, communities of practice, classroom) created a dynamic setting for Miguel where he is able to make connections and generate important information relevant for the project. In this dynamic setting, individuals draw selectively and strategically from two opposing categories to open new alternatives, and what seems to be oppositional categories can actually work together to generate new knowledge, new discourse, and new forms of literacy. On the other hand, Eduardo's funds of knowledge were very different from those observed from Miguel and Francisco. Eduardo's focus was mostly on the costs involved in the project, thus directing his efforts to finding solutions that would reduce costs for the project, efficiency, and simplicity. He emphasized the importance of capital investment:

> *I think one of the biggest things is always like save us money. That's one of the biggest things. Money and politics, there's always that and I think those are the big challenges.*

To a certain extent, his contributions were influenced greatly by his focus on business and how to create investments. He had previously been involved in an entrepreneurship class at school. Therefore, the production of knowledge and creation of new knowledge varies depending on the Discourses of every individual. Nonetheless, they were able to decide on one specific project and work on automatic doors for the students with disabilities. Perhaps most important is the feeling they shared regarding the need for help observed in their communities. Culturally, within underrepresented populations, there is often a sense of responsibility and desire to contribute positively to their communities. [12]

Overall, the students' funds of knowledge in this study were significant in brainstorming, developing solutions, and finding solutions to the community-based project. The students transformed their learning community by fostering new hybrid spaces that included a better participation role, motivation, and an effort to provide a social good. Members were bound together by their collective understanding of their community; they helped their community through mutual engagement, and produce a shared repertoire of communal resources.

It is also important to mention that Eduardo, Miguel, and Francisco's funds of knowledge were very diverse. Miguel and Francisco's funds of knowledge were similar to those reported by Gonzalez et al. [25] and Velez-Ibanez and Greenberg, [24] which are characteristic of the Mexican population in the U.S. borderland in areas such as farming, social networks and interdependency, trade, and different systems of exchange. On the other hand, Eduardo's funds of knowledge focused more on the social good, a very important aspect of engineering as a profession, but at the same time on a more individualistic structure concerning capital investment. The way in which he internalized his beliefs, the influence his church played on his social networks, and his Mexican-American household showed the complicated nature of funds of knowledge and the generation of new knowledge. Moreover, the students' beliefs and how they internalized those beliefs affected how they reacted to situations in their community and their motives to work on engineering projects. Although the three students shared common ideas and values, and they were involved in the same activities, their Discourses were very different. According to Rios-Aguilar et al., [30] Discourses are encountered not only in the household and the community, but also in more formalized institutions. The merger of these Discourses created a reconstructed form or a "third space" that is different for each individual, and new Discourse practices may emerge reflecting the everyday life and formal processes leading to hybrid practices and porous exchanges among them. [12]

Most of the research regarding funds of knowledge has involved qualitative studies that describe the students' households, family and community interactions, and systems of exchange and making these the main units of analysis. [25] This study was not the exception; however, the complicated nature of funds of knowledge was evident in the findings. There are certain limitations, like those in Eduardo's case, where it is possible that the funds of knowledge may be independent from the adults' social life. [30] The second limitation is that it does not distinguish among different types of learning. [31] Therefore, it is important to clearly identify the types of learning acquired in a community as well as defining the specific community being evaluated.

Another emerging theme during our interviews and discussions was the relationships they built with different individuals in their community. These thick social networks are also similar to those described by Gonzalez et al. [25]Social relationships facilitate the development and exchange of resources, including knowledge, skills, and labor, that enhance the households' ability to survive or thrive. Miguel, Francisco, and Eduardo were immersed in households with rich sources of pedagogical activity for the students.

Although their social networks were slightly different, trust was a common theme among them. Trust influenced their "systems of exchange," relationships, and therefore their thick funds of knowledge. Moreover, these social networks created social and cultural capital that may be overlooked by educators. It was through their social networks, social capital, and cultural capital that the students were able to access information necessary to work on the project. Social and cultural capital made a difference on the people they know, why they trust that group of people or individual, and increased or decreased the access to information or to other people. Rios-Aguilar et al. argue that social networks and funds of knowledge should be studied from a capital perspective and not only from a cultural perspective. [30] This will provide a better analysis for educational opportunity to all those under-represented students.

Conclusion

In an effort to address the challenges Latino students face in STEM, this project was intended to conduct and in-depth qualitative study that would enable engineering education to be more responsive to the needs of culturally and linguistically diverse learners. The study presented described how valuable are the funds of knowledge of Latino students when working on a community-based engineering project. This study also offers a unique insight to the ongoing problem of generating a different environment for Latino students in engineering that could be more inclusive. The cases presented showed that the thick funds of knowledge of the three students were extremely valuable for the engineering project. They were able to expose themselves to an engineering practice that integrated their everyday knowledge. The exchange of knowledge between engineers is similar to the relationships they have created with the members of the community and their parents.

Although research on funds of knowledge has been documented by many researchers, there are some limitations that must be addressed, such as research regarding the funds of knowledge of second and third generation Latinos and how this is different from Mexican-American families in the U.S. borderland. Future research must look at community-based engineering design activities for high school students, curriculum materials, and practices to help the linguistically and culturally diverse classrooms.

The study suggests that Latino students, although profoundly underrepresented in engineering, bring a wealth of knowledge and experiences that can be relevant to engineering design thinking and practice. Increasing our national STEM literacy and workforce readiness includes intensifying and diversifying student participation in the STEM learning experiences. By drawing from students' at-home experiences, bodies of knowledge, skills, and interests, engineering can be made more culturally responsive for Latino students. The findings presented on this study can be used to better understand the access and success of Latino students in engineering.

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