Funds of Knowledge and Literacies in Latino/a Youths' Community-Based Engineering Design Work

Amy Alexandra Wilson, Joel Alejandro Mejia, Indhira Hasbún, Daniel L. Householder, and Chris Hailey
Utah State University

STEM fields in the US continue to be dominated by people whose cultural backgrounds are White, English-speaking, and middle class (National Academy of Engineering and National Research Council, 2009). Many reasons have been offered to explain this phenomenon: Students' backgrounds may include worldviews, beliefs, and communicative practices that do not cohere with those practiced in STEM classrooms (Aikenhead & Jegede, 1999; Lee, 1999); instructional materials may present STEM fields as a-cultural, decontextualized practices with no evident connection to students' lives and communities, such as the routine completion of numerical exercises (O'Halloran, 2005); students' identities—shaped in part by their desired life trajectories, their personal histories, and the social groups by which they want to be accepted—may contrast with identities as STEM experts (Aschbacher, Li, & Roth, 2010); scientific and mathematical discourse, difficult for many adolescents to comprehend and use, may be especially challenging for those who are learning English (Fang, 2005); and societal inequities and prejudices may actively work to drive people of color and women out of STEM fields (Johnson, Brown, Carlone, & Cuevas, 2011).

To address some of these challenges, the National Research Council (2011) has argued that STEM instruction "needs to connect with students' own interests and experiences" (p. 2-4). 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 (Barton, Tan, & Rivet, 2008; Moje, Collazo, Carrillo, & Marx, 2001) and mathematics (Civil, 2002; Martin, 2006), very little research has been conducted on how the same task might be accomplished with adolescent English learners in the field of engineering. This study was therefore based on a theoretical model that embeds engineering design within social, cultural, and linguistic activity, seeking to understand how adolescent English learners draw from various linguistic, representational, and social resources as they work toward solving community-based engineering design challenges. Ultimately, we hope that obtaining information in these domains will enable engineering education to be more responsive to the cultural and linguistic needs of diverse learners.

A Sociocultural Model of Adolescent Engineering Design Processes. As late as 2005, engineering educational research was designated as a "new discipline" (Haghighi, 2005), one that largely presented engineering as a series of relatively decontextualized processes without rigorously accounting for the social and cultural contexts in which engineering education occurs (Godfrey & Parker, 2010; Stevens et al., 2008), with only a handful of studies serving as notable exceptions to this trend (e.g., Ambrose, Lazarus, & Nair, 1998; Bucciarelli, 1994; Tonso, 1996). We argue, however, that national calls for engineering diversity and inclusiveness (e.g., National Steering Committee of the National Engineering Education Research Colloquies, 2006) require a more situated view of adolescents' engineering design processes, one that embeds their designs within larger social and linguistic activity. Our theoretical model, outlined in the following section (see Figure 1), provides this situated view of engineering design.

Design processes. According to national educational frameworks (International Technology Education Association, 2000; National Assessment Governing Board, 2010) and a large body of research and theoretical literature (e.g., Asunda & Hill, 2007; French, 1999; Jonassen, 2000), a central and distinguishing feature of engineering is *design,* defined by Dym and colleagues (2005) 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). Using similar definitions, many researchers and theorists (Dixon & Johnson, 2011; Koen, 2003; Lewis, 2006) have conceptualized the work of engineers in terms of a series of design processes, identifying the specific methods necessary for producing successful designs among professional and novice engineers.

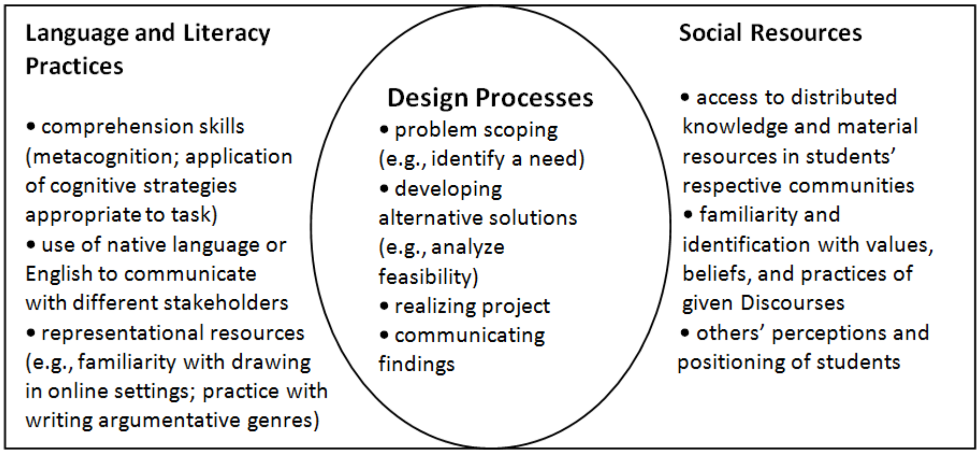

Figure 1. A sociocultural model of adolescents' engineering design process.

Reciprocity among elements of model. We close this description of the 'sociocultural model of adolescent engineering design processes' by clarifying that we view all three domains of the model—design processes, social resources, and language and literacy practices—as being mutually constitutive and reinforcing. Design processes, for example, entirely depend on receptive literacy practices such as locating and comprehending relevant texts during the information gathering stage, and expressive literacy practices such as producing representations used to reason about the design. Furthermore, although our visual model (Figure 1) separated "language and literacy practices" from "social resources," in essence we believe that language and literacy practices *are* a social resource, tightly intertwined with one's identity and participation in engineering Discourses. Moreover, we believe that the three domains are in some ways interchangeable; for instance, if one adolescent cannot understand a particular website (e.g., categorized as an ineffective *receptive literacy practice*), then he or she may know somebody in the neighborhood who can explain similar concepts more easily than the website (e.g., categorized as effectively drawing from a *social resource*). The contextualized nature of this sociocultural model enables us to paint a situated picture of adolescents' engineering design processes, which heretofore has been absent from the research literature.

Research Question

What design processes, social resources, and language and literacy practices do the Latina/o English learners use as they worked toward implementing a community-based engineering design? Grounded in our theoretical model, this research question seeks to identify potential connections among formal engineering design processes and adolescents' social resources and literacy practices. By identifying points of connection across the three domains, this study will provide a body of knowledge that works toward the construction of a "third space" in engineering education (cf. Moje et al. 2004), one that blurs boundaries between Latina/o adolescent' home Discourses and literacy practices, and formal engineering Discourses and literacy practices.

Method

Context of the study. Throughout the course of one school year (nine months), we followed three groups of Latino/a adolescents as they selected a problem in their communities that were of interest to them, and then sought to solve these problems through engineering design processes. We are currently in the middle of Year Two of the study, in which we follow an additional four groups as they select a problem in their communities and solve them through engineering design process. Each group met twice per month in local community locations of their choosing, such as at libraries or a pizza joint, 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.

The problems that the adolescents have selected/are currently selecting are as follows, which correlate with our descriptions of each group below.

Group One: improve and expand a small playground in their neighborhood.
Group Two: improve an existing device for restraining cats while giving them vaccination shots.
Group Three: design a wheelchair-accessible door for their high school.
Group Four: design a device that will decrease their parents' injuries in the workplace while lifting heavy objects (e.g., boxes, carcasses).
Group Five: design a playground for people in wheelchairs.
Group Six: design clothes that are mosquito repellent.
Group Seven: develop an improved method for harvesting water in the desert valley in which they live.

Each participant was given an I-pad and engineering notebook throughout the duration of the study. They were also given $20 with which they could purchase apps of their choosing. Students had access to wi-fi at their respective high schools and at the local libraries which they frequented; some of them had wi-fi at home as well.

Research design. Like previous studies that documented connections between students' funds of knowledge and formal scientific and mathematical Discourses (e.g., Basu & Barton, 2005; Moje et al. 2001; Nasir, 2002), this study is based on ethnographic methods of data collection and analysis (e.g., Barton, 2001; Murillo, 1999). As researchers who had studied connections between African American students' cultural practices and formal mathematics, Nasir and Saxe (2003) asserted that "ethnographic techniques are well-suited for identifying important sites for analysis in which tensions between ethnic and academic identities may arise" (p. 16). Kelly, Chen, and Crawford (1998) similarly argued that ethnographic inquiry is essential for describing scientific activities situated within local, social, and cultural contexts. Although the field of engineering education is not characterized by a robust history of ethnographic research to the same extent as other STEM fields (Godfrey & Parker, 2010), Foor, Walden, and Tryten (2007) nonetheless argued that qualitative methods are necessary in engineering educational research because they provide "a microphone for the voices of the marginalized to be heard. Ethnography of the particular allows us to hear each and every voice that would otherwise be lost in…statistical analyses" (p. 113). In sum, this study is grounded in a large body of theoretical and research literature suggesting that ethnographic methods are fitting for research purposes that seek to connect adolescents' everyday Discourses with formal engineering processes.

Participant selection and characteristics. To recruit participants, we visited four high schools located in rural Northern Utah. We presented the research to students in clubs such as Latinos in Action (LIA) and Mathematics, Engineering, and Science Achievement (MESA). In one school that did not have these clubs, the school counselor gathered students whom she thought would be interested in participating. Out of about 50 students who wanted to participate in the study, we selected 24 adolescents based on three criteria. First, they identified themselves as Latino/a, as Hispanic, and/or as being from a Spanish-speaking country (e.g., "I am Guatemalan.") Second, they had recently received English as a Second Language services. Third, they spoke Spanish as a first language. We did not require participants to have previous experience with engineering because we wanted to see how they drew from everyday funds of knowledge, as opposed to formal knowledge of engineering, to accomplish the task. Of the 24 participants, six of them had attended engineering courses in high school.

The researchers split the participants into seven groups based primarily on their location (e.g., students from the same region of the valley were grouped with others who also lived in that region of the valley). Most students were born in another country (Guatemala, Honduras, Mexico, Salvador), although some students had been born in the United States to one or more parents who had immigrated from another country (Argentina, Guatemala, Honduras, Mexico) and who spoke Spanish at home. The students in Groups Six and Seven attended a magnet school whose mission was to focus on STEM education, and several of their parents were engineers, university professors, or doctoral students in engineering. The students in the other groups had working class parents who held jobs at the local meat-packing plant, in the local dairy, as poultry workers, as car mechanics, as construction workers, as painters, or as valets. A few students helped their parents manage small businesses, such as local restaurants or yard-care businesses, which sometimes went in and out of insolvency. The groups' composition was as follows:

Group One: two females (sisters) and one male
Group Two: four females (one pair of sisters)
Group Three: three males
Group Four: one male and three females
Group Five: four females (two of whom were cousins who lived together)
Group Six: three males
Group Seven: three females (two of whom were cousins who lived together)

Background of researchers. Amy Alexandra Wilson is a literacy researcher who specializes in culturally responsive disciplinary literacy instruction for Latino/a and adolescents. Joel Alejandro (Alex) Mejia is a former metallurgical and aerospace engineer who is currently pursuing his doctorate in engineering education. Indhira Hasbún holds a BS in civil engineering and is currently pursuing her Masters degree in environmental engineering. Dan Householder was formerly the co-director of the National Center of Engineering and Technology Education, the President of the Council on Technology Teacher Education, and the President of the International Technology and Engineering Educators Association. He currently teaches doctoral-level courses on engineering education. Christine Hailey is a former aerospace engineer and is currently Dean of the College of Engineering at Utah State University. Alex and Indhira were born in Mexico and the Dominican Republic, respectively, and they conducted interviews and group meetings with the participants in Spanish when necessary.

Data sources. We collected four types of data. The first type of data was *audio- and/or video-recordings* of the adolescents' bi-monthly meetings in which they met to discuss what problems they wanted to address and in which they went about solving the problems. These audio- and video-recordings also included observations of students as they collected data in their communities, such as when Group Two interviewed veterinarians and workers at humane societies, or when Group One distributed surveys to people at a local park. In cases where the use of recording equipment was unethical due to lack of consent from others (e.g., people at the park), we took field notes.

Second, we conducted *interviews* with each adolescent about once per month. In the initial interview, we sought to learn more about the adolescents' backgrounds and life histories. In the ongoing interviews, we asked questions that sought to elicit the adolescents' language and literacy practices as well as their social resources. Oftentimes, interview questions were based on findings from previous group discussions. For instance, when Miguel (all names are pseudonyms) said he wanted to build a handicapped door that used a hydraulic device he had previously seen, we interviewed him about his experiences with using/fixing/maintaining/observing hydraulic devices at his workplace. (Miguel milked cows at a local dairy.)

The third type of data was *retrospective and concurrent protocols* (Ericcson & Simon, 1993; Smagorinsky, 1994) in which participants articulated their thinking while performing tasks that we believed might prove relevant to the engineering design process. For instance, students conducted concurrent protocols in which they thought aloud while seeking for relevant information on the Internet, explaining why they chose one site over another site. As a second example, we asked one student to think aloud while she played her favorite app, which was a fashion design app, as she explained why she made particular financial decisions or decisions related to style and materials selection. As a third example, we video-recorded Federico's thought processes while he was in the process of using machinery to milk a cow.

The fourth type of data was *adolescent-generated products,* which included representations generated throughout the design process; a record of the websites that they visited in relation to the engineering design task; more formal products, such as drafts of their final designs; and other relevant artifacts.

Data analysis. The first and second author are currently using a modified version of *constant comparative analysis* (Strauss & Corbin, 1998) to analyze the data. 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, our version of CCA was shaped by our theoretical model and by previous research connecting adolescents' everyday Discourses to science Discourses (e.g., Barton & Tan, 2009; Moje et al. 2001). Using these a priori codes and questions as well as our readings of the data, Amy Alexandra and Alex jointly developed codes which identified patterns in the data, and we are analyzing the whole data set together while mutually agreeing on each code (Smagorinsky, 2008). Indhira and Dan are conducting data audits, in which they read and discuss individual data excerpts—including the process and product behind the analysis—and confirm that our analysis of the data seems credible to them based on their familiarity with the data set and with the participants. Finally, we plan to invite the participants for feedback on our findings, although we have not yet done so.

Findings

Below, we describe six categories of social resources that we noticed in our preliminary analyses. We describe each type of social resource as well as how they connect to engineering design processes and/or language and literacy practices.

(1) *Workplace*. Many students' funds of knowledge related to their own or to their parents' workplaces. Workplace experiences provided students with a wealth of knowledge relevant to engineering, such as (a) the pre-eminence of safety, (b) economic considerations, and (c) consideration of trade-offs. In this section, we provide examples that illustrate what the research participants learned in each area.

Through their own or their parents' workplace experiences, students learned about the importance of making engineering designs that are *safe* on many different levels. For instance, Sofia helped her father clean and bandage a severe cut caused by machinery that sliced meat. Ariana and Katarina similarly tried to help their fathers who had back pain and hand pain due to their work lifting heavy boxes. From parents' and their own experiences with injuries caused on the workplace, students learned the importance of making designs that accomplished tasks effectively while still promoting and maintaining the safety of the humans who used the devices.

The participants also learned a variety of economic factors through their experience in the workplace. For instance, they learned about marketing through trying to sell commodities for their parents. As one example, Emilio learned from a young age how to use communicative techniques that would help his grandparents sell avocados from their farms. The adolescents sought to apply these techniques when sharing their proposed designs with clients who could provide the funding for their designs to be realized. Just as engineers must often consider their clients' tight budget while making decisions, students' workplace experiences taught them to consider constraints when allocating money. For instance, Miguel and Federico knew that, in order to earn bonuses when selling their milk to a supplier, they needed to produce milk with a specified, limited number of bacteria per unit. Yet their bosses could not afford high-end equipment for early detection of sick cows because the cost of this equipment would significantly reduce the profits of the dairy. From these experiences and others, the adolescents knew that the *ideal* solution (e.g., buying the best equipment) was often not the *optimal* solution because the ideal solution was often financially out-of-reach for the target population.

In addition to learning about constraints, which are essential to the engineering design process, the participants' workplaces also taught them about how to consider trade-offs, which is another central component of engineering design. Trade-offs include a value judgment as engineers consider which factors are more important than others. For instance, an engineer might make products out of sustainable materials, but these materials could cost more for clients as opposed to non-sustainable materials. In this case, engineers would have to weigh sustainability against cost prior to deciding on a final design. From their experiences in the workplace, students often saw cost weighed against workplace safety, often with cost coming out as the most valued factor. For instance, Miguel and Federico's boss would clean the dairy machinery by flushing it with an acid—which was a cheap method for maintaining the machinery and ensuring milk with lower bacteria—but this method also produced injuries among the workers who often inhaled the acid, which resulted in stinging eyes and throats. Ariana, Isabel, and Sofia's fathers similarly worked at meat-packing plants where workers' safety and environmental safety were usually placed second to cost efficiency in the bosses' decisions. These experiences—especially with their parents' injuries while at work—gave the adolescents a sense of the importance of ethics in engineering, including how costs need to be balanced against other, more humane considerations.

(2) *Health of Self and Family.* The adolescents' experiences with their own health, as well as the health of their families, were often rich sources of knowledge that enabled students to make more compassionate and effective engineering designs. For instance, Katrina had a medical condition that caused her to break about ten different bones throughout her lifetime, while Clara had an illness as a child that caused her to go deaf in one ear while progressively losing her hearing in the other. Emilio accompanied his mother to chemotherapy every other week, while Tito helped his younger brother with muscular dystrophy in and out of the shower and in out of bed every day.

Due to these illnesses, the adolescents were deeply motivated to learn a lot of scientific information about illnesses, such as how chemotherapy works to destroy cells that divide rapidly, how bone density affects breakages and the methods that are used to set bones, how the cochlea functions in the ear, and so forth. We imagine that these bodies of knowledge could have been used as adolescents devised products that would help the human body, although none of these adolescents chose to make products related to their own or their families' illnesses. Based on his experiences with his brother, however, Tito did propose to his group that they build a light-weight, transportable ramp that would work even on non-standard porches. He had helped his family to research and sample several available products on the market, but they had been unable to find a product they could afford that would work for his brother's needs in the particular duplex in which they lived. In other words, due to his experience with his brother's illness, Tito did market research on available products and identified a gap in the market that could be filled with a product, which is often one aspect of engineering design. He also had first-hand experience with the needs of people with disabilities—he identified that his slender mother, for instance, could help his brother get in and out of some devices, but not others, in which case he (a tall, stocky teenager) had to do the job. This experience gave him insight regarding how one device can be effective under some circumstances (one device could work well for strong, muscular people) but not under other circumstances (the same device would not work as well for slender people).

Several engineers mention empathy as an important part of the design process because often engineers must meet the needs of people whose circumstances are different from their own. We argue that the adolescents' experiences with illnesses developed this sense of empathy as adolescents learned first-hand that engineering, at its best, is about helping diverse people—such as people with diverse body types/conditions, people with diverse incomes, and people from diverse geographic regions—and not simply imagining more and better devices for the healthy and rich who live in resource-rich regions of the world.

(3) Travel across countries. Adolescents' travel across countries also served as another resource that connected to their design processes. Several devices or systems in their home countries were different than many devices in America, and consequently familiarity with multiple devices helped the adolescents develop multiple ways at looking to solutions to problems. Karina, for instance, had recently helped her father design a house, which an architect subsequently built in Salvador. This house served as a full-time resident for Karina's grandmother, as well as a part-time vacation home for Karina's family when they visited. Karina explained that, as opposed to many houses in the United States which are made of brick, wood, or other materials—many houses in Salvador are made of cement. She also explained that when Argentinian houses are made of cement, they are usually only one story tall because the cement and water are heavy and difficult to transport up to a second story.

She described how she and her father had to create extremely different house designs as compared to the house they had in America, in order to better account for the styles and available materials in their region in Argentina. For instance, they knew they needed to put iron bars on the window in order to keep out would-be thieves in their neighborhood, and they had to account for the nature of concrete when deciding how they would build a two-story home. As a second example, Federica helped her father build an outdoor mud and brick stove in Mexico, which was different than the stove she had in her kitchen in the U.S. In both of these cases and in many others, an international perspective gave the participants intimate and elaborate experience with how people may devise significantly different solutions to similar problems, and yet both solutions may get the job done.

(4) ***Household/yard tasks, construction, and maintenance.*** We found that the adolescents often helped their families with household and yard tasks, which served as a potentially rich resource for engineering design. One such task included caring for animals, such as goats, cats, and dogs. Members of Group Two, which built the restraining device for the cats, often drew on their experience with caring for animals while planning their design. For instance, they knew that "scruffing" a cat, or picking it up by its neck, often renders a cat more docile, and they sought to determine whether they could incorporate this element into their own restraint to make feral cats more docile. As a second example, Elena and Laura (sisters) helped their fathers lay stones in their backyard outside of their porch to prevent erosion, which later proved relevant to their playground design as they sought to prevent erosion of sand in the playground. As a final example, Nyla and Silvia watched their dad make and install metal fences and gates for their house. When they had questions about the material they should choose for their cat restraining device, they knew that their dad had experience with metal working, and they used his expertise to determine which type of metal should be used in the device.

(5) ***Popular cultural texts.*** Several of the students watched TV shows that gave them insight into the engineering design process as well. A few students watched included *Fetch.* In this series, in each episode, an adolescent was faced with a problem, such as that somebody lost his friend in a pinewood derby car race, and he wanted to build a car that could beat his friend in an upcoming race. Other students watched *How It's Made,* which describes how objects such as engines and bubble gum are made.

Eduardo enjoyed *Design Squad,* which he described in the following terms: "And what they do is that every single episode they have a different problem they're trying to solve. So they first start with a problem and like basically do a video presentation on it so then they could see it. They do a project where they find something that needs to be fixed. Like one of them was, I remember it was a water slide that they use down like a public swimming pool. And the thing is they had a water slide there but it had no water running from it. So it got really hot and then you couldn't even go down it, basically you'd get stuck. So they kind of then figured out what are some fun ways that you could make it work, get it wet, but without making it hard." Through watching this show and *Fetch*, Eduardo learned how different people come up with different solutions, each of which included merits and drawbacks, and he listened as professionals evaluated each design according to these merits and drawbacks. We argue that this process, too, gave him insight into the complexity of evaluating the merits and drawbacks of designs according to a set of criteria that varied according to setting (e.g., "fun" is important in waterslide designs but may not be relevant to all designs).

(6) ***Digital technologies.*** Students' experiences with digital technologies, such as apps and video games, likewise proved relevant to thinking like an engineer. Silvia, for instance, enjoyed playing with fashion apps in which she read client's specifications and then made designs that met those specifications. As she played the game, for instance, one client said she liked clothes with the following characteristics: collar, lace, long sleeves, and pleated. Under the assumptions that clients often do not specify all of their preferences, Silvia conducted other types of research by looking at the clothes that the client had worn in the past, noting what kinds of materials and colors she liked as well. Silvia then produced a final outfit for her client, which was evaluated and given a lot of points. We argue that this type of thinking relates to engineers who must meet the needs and preferences for their clients, many of whom do not specify all of the relevant criteria and constraints, leaving engineers to conduct additional research (Dym & Little, 2009).

As a second example of using apps to promote engineering thinking, Silvia played an app called *Design,* which required her to purchase machines and materials to make a clothing store, to design the layout of the store, and to use money from the store to purchase additional materials. As part of this game, Silvia had to consider whether to purchase a machine that would make her clothes 50% faster than her current machine. Silvia noted that the benefits of the machine would include making more clothes, which would ultimately lead to more money, but the downside of purchasing the machine would mean providing a lot of money at the outset, which was a risk if not enough clients purchased the product made by the machine. We argue that this game gave Silvia practice with working within constraints to manufacture products as she weighed trade-offs, which are hallmarks of thinking like engineers.

As a final example, we cite Mario's experience Sim City, which taught him several principles related to civil engineering. He learned about the importance of spatial reasoning, such as where to place industrial plants in relation to residential homes. He stated, "Mostly, the industrial parts gets really polluted, and a lot of germs. So you want it away from the city when you have the shops and stuff. Cause if you put an industrial part next to a house, the people there are going to start getting sick soon and stuff." He explained, consequently, he believed industrial plants should be built away from cities, especially where wind patterns tended to blow smoke away from people, to lead to healthier cities.

We had anticipated that "digital technologies" would often include the use of the Internet to search for materials and costs, but we found that this task proved difficult for the participants. For instance, the group who built the cat restraint device wanted the device to snap together using the same mechanism that holds a refrigerator door to the refrigerator. The group typed in "refrigerator magnets" and found images of magnets that people frequently place on fridges, but were unable to locate information regarding how fridge doors stuck to fridges. As a second example, Nyla sought to locate materials with which to make the cat restraint device, and found an app that listed different materials and their properties. The following interview excerpt highlighted her understanding of the app:

> *Researcher*: Earlier you said you didn't know what conditioner A means. Is there anything else here that you don't know what it means?
> *Natalia*: Yeah, what they're talking about. Just basically everything what they're talking about. Like elongation and hill stress and ten [a number listed for a property of a material]. Okay, I don't know what that is, and strength. And then AISI, what that stands for.

We found that, instead of locating information online, the group preferred instead to use other resources available to them. After this search proved difficult, Nyla asked her dad, who worked with metal around the house, to just tell her what material he thought they should use and why. The group later chose this material for their design. As a second example, Miguel had searched for legal codes related to the American with Disabilities Act, because he wanted to collect proof that his principal was legally obligated to install a handicapped door at his school. After scrolling through legal documents online, he was unable to locate or comprehend a text that would prove that the principal was legally obligated to install the door. Consequently, he asked one of his teachers, who was knowledgeable about the law and who supported Miguel's efforts, to instead just tell him.

Implications

This exploratory study suggests an initial framework from which high school engineering teachers can draw as they seek to integrate their Latino/a students' everyday funds of knowledge and social resources to more formal engineering design processes. This study suggests that Latino/a students, although they are profoundly underrepresented in engineering courses and in the engineering workforce, bring a wealth of knowledge and experiences that can are relevant to engineering design thinking and practice. We hope that, by drawing from students' at-home experiences, bodies of knowledge, skills, and interest, engineering can be made more culturally responsive for Hispanic students. More research can be conducted to determine whether this framework is a useful heuristic for Hispanic students from other rural areas or from urban areas.

Finally, this study also suggests that, in the information gathering stage of the design process, teachers may consider ways they can support students in locating information relevant to the design process and provide explicit comprehension instruction on the texts that they find since many of these texts seem to be difficult for adolescents to understand.

References

Aikenhead, G. S., & Jegede, O. J. (1999). Cross-cultural science education: A cognitive explanation of a cultural phenomenon. *Journal of Research in Science Teaching, 36,* 269-287.

Alvermann, D. E. (2004). Multiliteracies and self-questioning in the service of science learning. In E. W. Saul (Ed.), *Crossing borders in literacy and science instruction: Perspectives on theory and* *practice* (pp. 226-238). Newark, DE: International Reading Association and National Science Teachers Association.

Alvermann, D. E., & Wilson, A. A. (2011). Comprehension strategy instruction for multimodal texts in science. *Theory into Practice, 50,* 116-124.

Ambrose, S., Lazarus, B., & Nair, I. (1998). No universal constants: Journeys of women in engineering and computer science. *Journal of Engineering Education, 87,* 363-369.

American Association for the Advancement of Science. (1993/2009). *Benchmarks for science literacy.* Retrieved from http://www.project2061.org/publications/bsl/

Apedoe, X., & Ford, M. (2010). The empirical attitude, material practice, and design activities. *Science & Education, 19,* 165-186.

Aschbacher, P. R., Li, E, & Roth, E. J. (2010). Is science me? High school students' identities, participation, and aspirations in science, engineering, and medicine. *Journal of Research in Science Teaching, 47,* 564-582.

Asunda, P. A., & Hill, R. B. (2007). Critical features of engineering design in technology education. *Journal of Industrial Teacher Education, 44*, pp. 25-48.

Atkinson, R. (1998). *The life story interview.* Thousand Oaks, CA: Sage.

Atman, C. J., Adams, R. S., Cardella, M. E.,Turns, J., Mosborg, S., & Saleem, J. (2007). Engineering design processes: A comparison of students and expert practitioners. *Journal of Engineering Education, 96*, 359-379.

Atman, C. J., Cardella, M. E., Turns, J., & Adams, R. (2005). Comparing freshman and senior engineering design processes: An in-depth follow-up study. *Design Studies, 26,* 325-357.

Baldry, A., & Thibault, P. J. (2006). *Multimodal transcription and analysis: A multimedia toolkit and coursebook with associated on-line course.* London: Equinox.

Barton, A. C. (2001). Science education in urban settings: Seeking new ways of praxis through critical ethnography. *Journal of Research in Science Teaching, 38,* 899-917.

Barton, A. C., & Tan. E. (2009). Funds of knowledge and Discourses and hybrid space. *Journal of Research in Science Teaching, 46*, 50-73.

Barton, A. C., Tan, E., & Rivet, A. (2008). Creating hybrid spaces for engaging school science among urban middle school girls. *American Educational Research Journal, 45,* 68-103.

Barton, A. C., & Yang, K. (2000). The culture of power and science education: Learning from Miguel. *Journal of Research in Science Teaching, 37,* 871-889.

Basu, S. J., & Barton, A. C. (2005). Developing a sustained interest in science among urban minority youth. *Journal of Research in Science Teaching, 44,* 466-489.

Bouillion, L. M., & Gomez, L. M. (2001). Connecting school and community with science learning: Real world problems and school-community partnerships as contextual scaffolds. *Journal of Research in Science Teaching, 38,* 878-898.

Brickhouse, N.W., & Potter, J.T. (2000). Young women's scientific identity formation in an urban context. *Journal of Research in Science Teaching, 38,* 965–980.

Brilliant-Mills, H. (1993). Becoming a mathematician: Building a situated definition of mathematics. *Linguistics and Education, 5,* 301-334.

Brown, B. A. (2004). Discursive identity: Assimilation into the culture of science and its implications for minority students. *Journal of Research in Science Teaching, 41*(8), 810-834.

Bucciarelli, L. L. (1994). *Designing engineers.* Cambridge, MA: MIT Press.

Bursic, K. M., & Atman, C. J. (1997). Information gathering: A critical step for quality in the design process. *Quality Management Journal, 4,* 60-75.

Buxton, C. (2006). Creating contextually authentic science in a low performing urban elementary school. *Journal of Research in Science Teaching, 43,* 695–721.

Cardella, M. E. (2008). Which mathematics should we teach engineering students? An empirically grounded case for a broad notion of mathematical thinking. *Teaching Mathematics Applications, 27,* 150-159.

Carspecken, P. F. (1996). *Critical ethnography in educational research: A theoretical and practical guide.* New York: Routledge.

Celedón-Pattichis, S., Musanti, S., & Marshall, M. (2010). Bilingual teachers' reflections on students' native language and culture to teach mathematics. In M. Foote (Ed.), *Mathematics teaching and learning in K-12: Equity and professional development* (pp. 7-24). New York, NY: Palgrave McMillan.

Civil, M. (2002). Culture and mathematics: A community approach. *Journal of Intercultural Studies, 23,* 133-148.

Coiro, J. (2011). Predicting reading comprehension on the Internet: Contributions of offline reading skills, online reading skills, and prior knowledge. Journal of Literacy Research, 43(4) 352-392.

Coiro, J. & Dobler, E. (2007). Exploring the online comprehension strategies used by sixth-grade skilled readers to search for and locate information on the Internet. *Reading Research Quarterly, 42*, 214-257.

diSessa, A. A. (2004). Metarepresentation: Native competence and targets for instruction. *Cognition and Instruction, 22,* 293-331.

diSessa, A. A., Hammer, D., Sherin, B. & Kolpakowski, T. (1991). Inventing graphing: Metarepresentational expertise in children. *Journal of Mathematical Behavior, 10*, 117-160.

Dixon, R. A., & Johnson, S. D. (2011). Experts vs. novices: Differences in how mental representations are used in engineering design. *Journal of Technology Education, 23,* 47-65.

Draper, R. J. (2002). School mathematics reform, constructivism, and literacy: A case for literacy instruction in the reform-oriented math classroom. *Journal of Adolescent & Adult Literacy, 45,* 520-529.

Dryburgh, H. (1999). Work hard, play hard: Women and professionalization in engineering—adapting to the culture. *Gender and Society, 13,* 664-682.

Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Liefer, L. J. (2005). Engineering design thinking, teaching, and learning. *Journal of Engineering Education,* 103-120.

Emerson, R. M., Fretz, R. I., & Shaw, L. L. (1995). *Writing ethnographic field notes.* Chicago & London: University of Chicago Press.

Ericcson, K. A., & Simon, H. A. (1993). *Protocol analysis: Verbal reports as data.* Cambridge, MA: MIT Press.

Fang, Z. (2005). Scientific literacy: A systemic functional linguistics perspective. *Science Education, 89,* 335–347.

Foor, C. E., Walden, S. E., Tryten, D. A. (2007). "I wish that I belonged more in this whole engineering group:" Achieving individual diversity. *Journal of Engineering Education,* 103-115.

French, M. (1999). *Conceptual design for engineers*. London: Springer.

Gee, J. P. (2005). *An introduction to discourse analysis: Theory and method* (2nd ed.). London: Routledge.

Gee, J. P. (2008). *Social linguistics and literacies: Ideology in discourses* (3rd ed.) London: Routledge.

Glaser, B., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research.* Chicago, IL: Aldine.

Godfrey, E., & Parker, L. (2010). Mapping the cultural landscape in engineering education, *Journal of Engineering Education, 99*, 5-22.

González, N., Moll, L. C., & Amanti, C. (Eds.). (2005). *Funds of knowledge: Theorizing practice in households, communities, and classrooms.* Mahwah, NJ: Lawrence Erlbaum.

Gutiérrez, K. D. (2008). Developing a sociocritical literacy in the third space. *Reading Research Quarterly, 43,* 148-164.

Hacker, S. (1983). Mathematization of engineering: Limits on women and the field. In J. Rothschild (Ed.), *Machina ex dea: Feminist perspectives on technology* (pp. 38-58). New York, NY: Pergamon Press.

Haghighi, K. (2005). Quiet no longer: Birth of a new discipline. *Journal of Engineering Education, 94,* 351–53.

Hailey, C., Austin, C. Denson, C., & Householder, D. (2011). *Investigating influences of the MESA program upon underrepresented students*. Paper presented at the meeting of the American Society for Engineering Education, Vancouver, BC.

Halliday, M. A. K., & Martin, J. R. (1993). *Writing science: Literacy and discursive power*. Pittsburgh: University of Pittsburgh Press.

Hayes, D. P. (1992). The growing inaccessibility of science. *Nature, 30,* 739-40.

Heath, S. B. (1983). *Ways with words: Language, life and work in communities and classrooms.* New York, NY: Cambridge University Press.

Householder, D. L. (Ed.). (2011). *Engineering design challenges in high school STEM courses: A compilation of invited position papers*. Retrieved from http://ncete.org/flash/pdfs/Engr%20Design%20Challenges%20Compilation.pdf.

Hsu, P.-L., Roth, W-M., Marshall, A., & Guenette, F. (2009). To be or not to be? Discursive resources for (dis-)identifying with science-related careers. *Journal of Research in Science Teaching, 46,* 1114-1136.

Hull, G. A., & Nelson, M. E. (2005) Locating the semiotic power of multimodality. *Written Communication, 22*, 224-261.

Hull, G. A., & Rose, M. (1990). 'This wooden shack place': The logic of an unconventional reading. *College Composition and Communication, 41,* 287-298.

International Technology Education Association. (2000). *Standards for Technological Literacy.* Reston, VA: Author.

Johnson, A., Brown, J., Carlone, H., & Cuevas, A. K. (2011). Authoring identity amidst the treacherous terrain of science: A multiracial feminist examination of the journeys of three women of color in science. *Journal of Research in Science Teaching, 48,* 339-366.

Jonassen, D. H. (2000). Toward a design theory of problem solving. *Educational Technology Research and Development, 48*(4), 63-85.

Kelly, G. J., Chen, C., & Crawford, T. (1998). Methodological considerations for studying science-in-the-making in educational settings. *Research in Science Education, 28,* 23-49.

Klein, P. D. (2006). The challenges of scientific literacy: From the viewpoint of second generation cognitive science. *International Journal of Science Education, 28,* 143–178.

Koen, B. V. (2003). *Discussion of the methods: Conducting the engineer's approach to problem solving.* New York: Oxford University Press.

Lee, C. D. (2001). Is October Brown Chinese? A cultural modeling activity system for underachieving students. *American Educational Research Journal, 38,* 97-141.

Lee, C. D. (2007). *Culture, literacy, and learning: Taking bloom in the midst of the whirlwind.* New York: Teachers College Press.

Lee, O. (1999). Science knowledge, world views, and information sources in social and cultural contexts: Making sense after a natural disaster. *American Educational Research Journal*, 36, 187-220.

Lewis, S. Mclean, E., Copeland, L., & Lintern, S. (1998). Further explorations of masculinity and the culture of engineering. *Australian Journal of Engineering Education, 8,* 59-78.

Lewis, T. (2006). Design and inquiry: Bases for an accommodation between science and technology education in the curriculum? *Journal of Research in Science Teaching, 43*, 255-281.

Martin, D. (2006). Mathematics learning and participation in African American context: The co-construction of identity in two intersecting realms of experience. In N. Nasir & P. Cobb (Eds.), *Diversity, equity, and access to mathematical ideas* (pp. 146–158). New York: Teachers College Press.

Martino, W. (1999). 'Cool boys', 'party animals', 'squids' and 'poofters': Interrogating the dynamics and politics of adolescent masculinities in school. *British Journal of the Sociology of Education, 20,* 239-263.

Mcilwee, J., & J.G. Robinson. (1992). *Women in engineering: Gender, power, and workplace culture.* Albany, NY: State University of New York Press.

Moje, E. B. (2004). Powerful spaces: Tracing the out-of-school literacy spaces of Latino/a youth. In K. M. Leander & M. Sheehy (Eds.), *Spatializing literacy research and practice* (pp. 15-38). New York: Peter Lang.

Moje, E. B. (2008). Foregrounding the disciplines in secondary literacy teaching and learning: A call for change. *Journal of Adolescent & Adult Literacy, 52,* 96-107.

Moje, E. B., Collazo, T., Carrillo, R., & Marx, R. W. (2001). "Maestro, what is quality?": Language, literacy, and discourse in project-based science. *Journal of Research in Science Teaching, 38,* 469-498.

Moje, E. B., Ciechanowski, K., Kramer, K., Ellis, L., Carrillo, R., & Collazo, T. (2004). Working toward third space in content area literacy: An examination of everyday funds of knowledge and discourse. *Reading Research Quarterly, 39*, 38-71.

Moll, L. C., Amanti, C., Neff, D., Gonzalez, N. (1992). Funds of knowledge for teaching: Using a qualitative approach to connect homes and classrooms. *Theory into Practice, 31*, 132-141.

Murillo, E. (1999). Mojado crossings along neoliberal borderlands. *Educational Foundations, 13*(1), 7-21.

Nasir, N. S. (2000). "Points ain't everything": Emergent goals and averages and percent understandings in the play of basketball among African-American students. *Anthropology & Education Quarterly, 31*, 283–305.

Nasir, N. S. (2002). Identity, goals, and learning: Mathematics in cultural practice. *Mathematical Thinking and Learning, 4,* 213-247.

Nasir, N. S., & Saxe, G. B. (2003). Ethnic and academic identities: A cultural practice perspective on emerging tensions and their management in the lives of minority students. *Educational Researcher, 32*(5), 14-18.

National Academy of Engineering and National Research Council. (2009). *Engineering in K-12 education: Understanding the status and improving the prospects.* Washington DC: National Academies Press.

National Assessment of Educational Progress (2007). *The Nation's Report Card on Writing.* Washington DC: Author. Retrieved from http://nces.ed.gov/nationsreportcard/pdf/main2007/2008468_1.pdf

National Assessment of Educational Progress. (2011). *The Nation's Report Card on Reading.* Washington DC: Author. Retrieved from http://nationsreportcard.gov/reading_2011/summary.asp

National Assessment Governing Board. (2010). *Technology and engineering literacy framework for the 2014 National Assessment of Educational Progress (NAEP).* Washington DC: Author. Retrieved from http://www.edgateway.net/cs/naepsci/print/docs/470

National Research Council. (2011). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* Washington DC: National Academies Press.

National Steering Committee of the National Engineering Education Research Colloquies. (2006). The research agenda for the new discipline of engineering education. *Journal of Engineering Education, 95,* 259-261.

Norris, S. P., & Phillips, L. M. (2003). How literacy in its fundamental sense is central to scientific literacy. *Science Education, 87,* 224–240.

O'Halloran, K. L. (2005). *Mathematical discourse: Language, symbolism, and visual images.* New York: Continuum.

Orellana, M. F., & Reynolds, J. (2008). Cultural modeling: Leveraging bilingual skills for school paraphrasing tasks. *Reading Research Quarterly, 43*, 48–65.

Reveles, J. M., Cordova, R., & Kelly, G. J. (2004). Science literacy and academic identity formulation. *Journal of Research in Science Teaching, 41,* 1111-1144.

Rosenblatt, L. M. (1994). The transactional theory of reading and writing. In R. B. Ruddell, M. R. Ruddell, & H. Singer (Eds.), *Theoretical models and processes of reading* (4th ed.; pp. 1057-1092). Newark, DE: International Reading Association.

Rubin, H. J., & Rubin, I. S. (2005). *Qualitative interviewing: The art of hearing data* (2nd ed.). Thousand Oaks, CA: Sage.

Seiler, G. (2001). Reversing the ‘‘standard’’ direction: Science emerging from the lives of African American students. *Journal of Research in Science Teaching, 38*, 1000–1014.

Smagorinsky, P. (1994). *Speaking about writing: Reflections on research methodology.* Thousand Oaks, CA: Sage.

Stevens, R., O’Connor, K., Garrison, L., Jocuns, A., & Amos, D. M. (2008). Becoming an engineer: Toward a three dimensional view of engineering learning. *Journal of Engineering Education, 97,* 355-368.

Stoyner, H. (2002). Making engineering students—making women: The discursive context of engineering education. *International Journal of Engineering Education, 18,* 392-399.

Strauss, A., & Corbin, J. (1998). *Basics of qualitative research: Techniques and procedures for developing grounded theory.* Thousand Oaks, CA: Sage.

Tan, E., & Barton, A. C. (2008). Unpacking science for all through the lens of identities-in-practice: the stories of Amelia and Ginny. *Cultural Studies of Science Education, 3,* 43–71.

Tate, W. F. (1995). Returning to the root: A culturally relevant approach to mathematics pedagogy. *Theory into Practice, 34,* 166-173.

Tonso, K. L. (1996). The impact of cultural norms on women. *Journal of Engineering Education, 85,* 217-225.

Ullman, D. G. Wood, S., & Craig, D. (1990). The importance of drawing in the mechanical design process. *Computers and Graphics, 14,* 263-274.

Upadhyay, B. (2006). Using students’ lived experiences in an urban classroom: An elementary school teacher’s thinking. *Science Education, 90,* 94–110.

Vélez-Ibáñez, C. G., & Greenburg, J. B. (1992). Knowledge and transformation of funds of knowledge among U.S.-Mexican households. *Anthropology & Education Quarterly, 23*, 313-335.

Walden, S. E., & Foor, C. (2008). “What’s to keep you from dropping out?”: Student immigration into and within engineering. *Journal of Engineering Education, 97,* 191-208.

Walker, M. (2001). Engineering identities. *British Journal of Sociology of Education, 22,* 75-89.

Warren, B., Ballenger, C., Ogonowski, M., Rosebery, A. S., Hudicourt-Barne, J. (2001). Rethinking diversity in learning science: The logic of everyday sense-making. *Journal of Research in Science Teaching, 38,* 529-552.

Welch, O. & Hodges, C. (1997). *Standing outside on the inside: Black adolescents and the construction of academic identity*. Albany, NY: State University of New York Press.

Wilson, A. A. (2011). A social semiotics framework for conceptualizing content area literacies. *Journal of Adolescent & Adult Literacy, 54*, 435-444.

Wilson, A. A., Chavez, K., & Anders, P. (2012). “From the Koran and Family Guy”: Expressions of identity in English Learners’ digital podcasts, *Journal of Adolescent & Adult Literacy, 55,* 374-384.

Yore, L. D., & Treagust, D. F. (2006). Current realities and future possibilities: Language and science literacy: Empowering research and informing instruction. *International Journal of Science Education, 28,* 291-314.