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Making the Funds of Knowledge of Low Income, First Generation (LIFG) Students Visible and Relevant to Engineering Education

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Abstract

Though engineering is often perceived as a pathway of upward mobility in the United States, very little is known about the experiences of undergraduate engineering students who come from low-income backgrounds or are the first in their families to attend college. The scant research that does exist about low income, first generation students (LIFGs) is grounded in a deficiency model, focusing on what these students lack. Our project breaks with the existing scholarship by identifying the ways in which LIFG knowledges and experiences outside the classroom, including the practical knowledge they develop in their lives and at work, could offer innovative ways for all students to define, solve and design for pressing engineering problems. Through ethnographic and collaborative research with LIFGs at a public engineering university and a community college, we identify students' funds of knowledge, or the knowledge gained from students' family and cultural backgrounds, that is crucial to engineering innovation but neglected in the curriculum they encounter in college. These funds of knowledge include defining and solving problems in the midst of financial and material scarcity; building, fixing, and adapting technical artifacts and systems; and empathizing with marginalized groups and communities. We suggest that these knowledges position LIFGs as effective innovators of engineering design for community development, though few pursue this path because of financial constraints. Finally, we identify future pathways of this exploratory research, including a) an international collaboration investigating the role of socioeconomic class for teaching and learning about engineering design and community engagement; b) a mentoring program between the engineering university and community college under study, including a university outreach program to assist LIFGs in enhancing their résumés; and c) strategies to bring LIFG funds of knowledge into engineering science and design courses.

Introduction

The goal of our research project is to discover how innovation and creativity in engineering problem solving can be fostered by integrating the knowledge and experiences of low-income and first-generation students (LIFGs) into engineering education. Broadening participation is a key feature of engineering education reform, but dominant definitions of diversity focus on gender, racial and ethnic minorities and persons with disabilities, leaving socioeconomic inequality – and its link to the other underrepresented demographic categories – mostly unexamined. The scant research that does exist about LIFGs is grounded in a deficiency model, focusing on what these students lack. This project breaks with the existing scholarship by identifying the ways in which LIFG knowledge and experience outside the classroom, including the tacit knowledge they develop in their lives and at work, could offer innovative ways for all students to define, solve and design for pressing engineering problems. Through ethnographic and collaborative research with LIFGs at a public engineering university and a community college, we identify students' *funds of knowledge*, or the knowledge gained from students' family and cultural backgrounds, that is crucial to engineering innovation but neglected in the curriculum they encounter in college. This is a radically different approach to understanding "diversity," as it explicitly includes socioeconomic class background as a potential resource rather than a hindrance. This exploratory, interdisciplinary research lays the foundation to integrate those findings into future work on engineering education research and diversity initiatives.

What we already know about LIFGs

Studies of low-income students in STEM in general and engineering in particular almost exclusively focus on students of color. In effect, this research studies socioeconomic class by studying race and ethnicity. While many low-income and first-generation students are also racial and ethnic minorities, not all students of color experience socioeconomic inequality. Moreover, this analytic frame misses many poor white students who do not have access to the same networks and support groups as do their peers who are students of color (e.g. Minority Engineering Programs, Society of Hispanic Professional Engineers, National Society of Black Engineers, etc.).

In fact, socioeconomic inequalities, as distinct from racial and ethnic inequalities, rarely appear in definitions of diversity in STEM education and workforce reform, as demonstrated by a common statement in NSF solicitations: "Throughout this [NSF] solicitation, the term underrepresented groups will refer to and include the following: women, persons with disabilities, and ethnic/racial groups which are in the minority in engineering such as African Americans, Hispanics, Native Americans, Alaska Natives, and Pacific Islanders." Even though these categories intersect with socioeconomic inequalities, this dimension itself is often overlooked or ignored, leading Michele Strutz and her colleagues[1] to call low-income students the "invisible minority." Overcoming this blindspot is crucial, since the existing focus on ethnicity and gender has "failed to eliminate disparities in engineering participation and degree completion."[2]

Studying socioeconomic inequalities in education presents unique challenges in terms of definition and measurement. The U.S. Department of Education's definition of socioeconomic status (SES) as an individual or family's relative economic and social ranking is influential, and measurements encompass a numerical scale of family income and levels of parents' education and type of occupation, and student self-reports, all of which present their own limitations.[2-3] For example, nine out of ten Americans identify themselves as members of the middle class, although the federal poverty rate hovers around 15 percent. This phenomenon is partially traceable to the pervasive popular assumption that *class* is not a salient force in American society and that *socioeconomic status* is a marker of individual effort. This narrative is especially significant in engineering, a field historically identified as a pathway of upward mobility and with many historical connections to workshops, craftsmanship, construction sites, etc., spaces and practices often associated with people from low-income backgrounds. Throughout this project we will use the term LIFG to make visible the experiences of students who come from low-income backgrounds and are the first in their family to attend college.

While it is difficult to untangle the influence of gender, race and ethnicity from socioeconomic inequality in understanding student enrollment and retention, the little research in engineering education that exists suggests that it is salient. Undergraduates whose family incomes were in the highest quarter enroll in engineering programs in higher numbers compared with their peers.[1,6] On average, students entering colleges and universities with large numbers of engineering undergraduates attend high schools with more economically privileged students.[2] Significant differences also exist in retention and graduation rates between LIFG students and their peers.[1]

Adding context to this troubling difference is the finding that LIFG students reported greater feelings of financial pressure and curriculum overload, as to be expected, but also lower family support, confidence in technical skill sets, satisfaction with instructors and satisfaction with the overall college experience.[3] Despite these trends, very little research examines LIFGs in engineering education, even though "traditional" engineering students – white males, aged 18-24, middle class, strong in math and science–are no longer the majority in higher education.[7] Our project seeks to make this neglected demographic category visible and relevant to engineering education.

Methods

To better understand the experiences of LIFG students and their unique contributions to engineering problem definition, solving, and design, we are conducting ongoing ethnographic research with LIFG students at the Colorado School of Mines (CSM), a state engineering university, and the nearby Red Rocks Community College, which sends the most transfer students to CSM. In the first year of the project, we enrolled 14 LIFG students to participate in the project, including 5 women, 5 Latinos, 2 rural farming/ranching students, 5 parents, 4 community college students, and 2 university students who had transferred from community colleges. We recruited students by advertising the research project on relevant campus email lists and by visiting classes. Because of the complexities inherent to defining "low income" status, we did not set thresholds but invited students to *self-identify* as LIFGs. We screened students for appropriate fit for the project in an initial interview.

Our primary research method is semi-structured interviewing. We completed 55 in-depth ethnographic interviews, which lasted between 60 and 120 minutes each. In the first semester of research, the first interview on *location* aimed at revealing the student's social location in and relationships with family, neighborhood, peer and school systems, jobs, engineering education, and other social institutions, such as government agencies, the penal system, and others. We also explored the student's *desire* to obtain an engineering degree and their hopes for what they wanted to do with it after graduating. The second interview on *knowledge* aimed at revealing how the student's location shapes their multiple knowledges, including practical or tacit knowledge. The third interview focused on the role that the senses played in the student's knowledge and practical activity, including tactile sensing which plays a significant role in the manual labor jobs and household tasks encountered by LIFG students.

Interviews during the second semester with generally the same group of students explored each one's *funds of knowledge (FoK)*, a term that refers to bodies of knowledge and skills that working class families possess to survive and make a living even in the midst of economic dislocations. Before the first interview, students mapped their FoK through a writing and diagramming exercise. The interview then focused on exploring those FoK, with particular attention to the communities of practice involved in their teaching and cultivation. The second interview linked those FoK with engineering knowledge, and the third interview explored links between their FoK and humanitarian engineering or engineering design for sustainable community development.

We also conducted *participant-observation activities* with students in their places of work, when it was possible to do so. Participant observations were sporadic and difficult because of the uncertainty and instability of their jobs, as well as the supervision under which they labored. Some participants did clerical work in offices under managerial supervision, while others worked as caretakers in assisted living or in an airport behind the security perimeter. We were able to engage in five participant-observation activities, including: an observation of a participant working as ski technician in a shop, waxing skis, fitting ski equipment for renters, and managing the different operations of the ski shop; a classroom observation at a pre-engineering class at community college; an observation of a student working on a school-sponsored research project; and an observation of a student fixing his truck while on campus.

Finally, we developed and hosted two day-long collaborative activities in which the LIFG students worked together to redefine and solve traditional engineering problems in ways that made their backgrounds and experiences (including their funds of knowledge) relevant and valuable to understanding engineering concepts. The students designed hands-on activities that could be used by professors to teach engineering concepts in new ways that value LIFG FoK and engage/develop all students' hands-on knowledge. We also facilitated discussions and written reflections of how learning and doing engineering in this different way—by explicitly integrating and valuing their own FoK into the process of problem definition, solving, and design—influenced their self-efficacy.

Our Students

The students enrolled in our project represent the major sections of low income populations in Colorado's political economy. One group comprises low-income young people who come to Colorado attracted by the job possibilities in the ski and construction industries in the Colorado Rockies. Most of these seasonal jobs do not require formal credentials or high levels of social capital. In fact, they often do not even require proof of legal permission to work. These jobs often provide perks such as ski lift passes, and on-site room and board. Sometimes, these youth hold jobs in both industries, working in construction during the week and as ski-lift operators during weekends. Some are able to enroll in high school or the community college in Summit County. The second group is comprised of LIFG youth from the Colorado flatlands, the plains east of Front Range urban corridor that connects Colorado Springs-Denver-Fort Collins. They come from families dedicated to ranching/farming and/or natural gas extraction operations. These youth are often first-generation engineering students that enroll at CSM attracted by relatively low in-state tuition and the prospects of high salaries in the extractive industries after graduation.

The third group includes students connected to the service sector of the Denver metropolitan area (population 2.6 million in 2012). Many of students and their families work to make a living as truckers, nurses, language tutors, waiters, cleaners, auto mechanics, clerical workers, and similar jobs. One of our LIFG students, for example, works three jobs as a truck driver/mechanic for his family business, as a sales person at Denver International Airport, and as a mover/lifter during and after estate sales – all the while as a full-time engineering student at CSM. Another works three jobs – as a nurse in an assistive care home for the elderly, a Spanish tutor for business people, and a clerical assistant on campus – while being a full-time engineering student at CSM.

In the midst of this economic activity, CSM continues to be positioned as a “best bargain school” where students wanting to major in financially rewarding careers like petroleum engineering benefit from relatively low tuition and little expectations of possessing the kinds of social and cultural capitals associated with Ivy League schools. Furthermore, CSM’s location with respect to this economic activity allows many LIFG students to *live* in working class neighborhoods in the Denver metropolitan area, continue to *work* in places where they can earn higher incomes, and *attend engineering school* at CSM’s suburban campus.

Funds of Knowledge

The term funds of knowledge (FoK) was originally coined by a team of scholars conducting research with Mexican-American youth and households “to refer to the historically accumulated and culturally developed bodies of knowledge and skills essential for household or individual functioning and well-being.”[8] The original FoK research and the majority of the studies that have followed it focus on ethnic communities, especially Latinos living in the United States.[8-13] Approximately a third of our LIFG students were Latinos, who are the largest ethnic minority group in Colorado as well as at both the engineering university and community college where we conducted research. Yet through our work with Latino as well as poor white students from both urban and rural backgrounds, we discovered FoK that are common to low-income, first-generation students in general – a significant finding that points to the importance of socioeconomic class for shaping the knowledges of nontraditional students in general, rather than just one ethnic/racial group in particular.

The FoKs identified in the existing research and our own rarely appear in formal classroom settings, especially in engineering courses, though they have great potential utility for enhancing student learning. FoKs connect students’ experiences and learning inside and outside of the classroom and provide a different model of teaching and learning that privileges children’s interests, questions, and active participation in finding solutions.

The FoK identified in the original study[8] were grounded in the rural ranching activities of the Mexican-American families: agriculture and mining, including ranching and farming; economics, including business and household management; material and scientific knowledge, including construction, repair, medicine and religion. As described in the case studies below, there are areas of overlap and as well as gaps between these FoKs in the Mexican-American families and those carried by the LIFG students in Colorado. Our rural LIFG students shared similar FoKs in ranching, farming, gardening, and landscaping. The majority had engaged in construction work either for employment or around their own households, and men in particular had experience operating and fixing machinery. Those who were single parents or the caretakers of younger siblings, cousins and other family members shared similar FoKs in household management.

In addition to those similar FoKs already identified in the literature, we identified LIFG students’ FoKs in empathizing with others and deftly managing social relations and institutions. These knowledges are crucial for navigating institutions of higher education and engineering courses, as well as for practicing engineering that is aware and responsive to its social context. Here we present the cases of five students to demonstrate not simply the students' unique FoKs, but their relevance for engineering and engineering education.

FoKs in choosing engineering: Brian

Brian explained his identification with the LIFG category by stating that unlike the "19-year-olds who drive Beamers to school and don't have to pay for their education or work I have to work if I want to eat." He came to engineering in his late 20s with a long history of manual and service work experience and a degree in marketing. His father was an electrician, and his mother was a secretary. Because they never had extra money growing up, he learned from a young age how to fix things around the house cheaply and spent a lot of time watching his dad tinker and work in their garage. He also credits his grandparents, with whom he would spend a couple of weeks on the farm every summer, for his abilities to reuse materials and things in creative ways for new purposes. They grew up during the Depression, which means that nothing ever went to waste and they solved their own problems with things they already had available. For example, they invented a "chip clip" before it existed, but never patented it, prompting his grandmother to always tell him to patent his own inventions.

Because of these experiences growing up, one of Brian's biggest passions is inventing things and prototyping them, from snowboards to specialized microphones and speakers. After working a string of service jobs (as a golf caddy, clerk, construction and framing laborer, telemarketer, and RV painter), he set out to make his own business manufacturing and selling the snowboard training equipment he invented. He supported himself by teaching kids how to do snowboard tricks (in the winter) and wakeboarding tricks (in the summer). He switched tracks to pursuing a marketing degree when people from another snowboarding company told him that it would take him a long time to turn a profit because the market was so small. When it became difficult to find meaningful work with his marketing degree, he went back to school for engineering.

Engineering appealed to Brian because it let him do something he enjoys – taking things apart and making things to prototype – while providing security. Security for him meant a reliable and good paycheck, work that did not tax his body, and a job that he could do even if he injured himself doing the sports (gymnastics, skiing, jumps, etc.) he loves. As a young adult, he lost his job as a framer when he injured his hand, and he remembered painting RVs with guys whose "visible age" and "actual age" did not correspond because they spent all day breathing in paint fumes. Perhaps most influentially, he remembers the "physicality" of his father's labor as an electrician. A hurting back put him out of work, and he routinely "worked his butt off," sometimes for lesser pay than he should have received, depending on the jobs to which he was assigned. "I don't want to be where he was," Brian said.

Engineering was an unlikely pathway for Brian, since his father also shared his frequent frustrations with engineers with him as he was growing up. He vividly remembers his father "bitching about damn engineers" who "think they are big and smart when they have never actually looked at something and asked, 'Does it fit? Does it work?' There is a big difference between theoretically correct and physically correct." But Brian's FoKs in creating things—and listening to people who work with their hands—pushed him to go into engineering and attempt to change it. Brian feels an intense desire to change the way engineers interact with technicians and practice engineering themselves. His experiences as a student, intern and now practicing engineer cause him to believe that engineers do better work when they have to build and manipulate real things in the real world, rather than simply abstract representations on paper. But doing that requires a willingness to talk with and learn from people who work with their hands and install and maintain the systems designed by engineers. "I'm interested in being in their world, getting muddy, getting dirty, touching ball valves. Being hands on helps build relationships," he explained. He thinks his dad would be proud of him for being the better kind of engineer who listens to technicians.

FoKs in choosing an engineering major: Faith

Faith grew up in a highway exit town where the choices for teenagers were limited to work in the service industry, serving mostly privileged people on their way to the ski resorts (waitressing, ski rentals, coffee shops). Raised by a single mother, Faith learned at very early age to do her own home repairs (including dry walling her room) and build a garden of her own (including composting) where she would find time away from the many kids that her mom had to care for in a home-based day care to make a living. Since then, Faith built her FoKs around things mechanical and things environmental. Her knowledge of mechanics developed by working as a technician in a ski tuning shop since her teenage years, learning about friction, metals, melting points, etc.; working as a cook learning about boiling points; and hanging out with friends who work on cars and wooden decks. Her knowledge of the environment comes from her mom who grew up in a ranch in Wyoming and taught her how to garden and compost, and from volunteering in a community garden where she learned about the interrelationships between the garden and the pollution created by the highway, brought in by the main creek running through town, and in nearby lands.

Having to deal with the complexities of single motherhood and very limited job and educational options, Faith enrolled in a community college while keeping a full-time job. She began exploring psychology and philosophy, as she was considering following her mother's footsteps into early childhood education. Wanting a high paying job to support her son and move out of poverty, Faith began exploring engineering through an Engineering Club at the community college and eventually transferred to Mines, where she faced the decision of having to choose an engineering major. Coming into Mines with a significant number of transfer credits, Faith dove into engineering science courses (statics, circuits), engineering labs, advanced mathematics and a sophomore-level design class. She enrolled in mechanical engineering and in a humanitarian engineering minor in Spring 2014. After a frustrating experience in Statics, a course that she associated directly to mechanical engineering, she decided to switch majors to Environmental engineering by Fall in spite of her FoK in mechanics. She was extremely frustrated with the step-by-step formulaic process that her teacher taught in statics as it removed all creativity and desire for understanding of the physical phenomena. Realizing that most of her 18-yr old classmates are accustomed to this process and "just listen and do it" [her tone of voice actually hints that they do this uncritically], in contrast, she says: "I actually stop and wonder if this is the right thing that I should be doing [amazing sense of ethical responsibility towards her knowledge] or if this process is actually going to teach me what the professor wants to teach me [amazing sense of meta-cognition]." Realizing that her critical reflection takes more time and does not necessarily lead to a quick and precise answer, as the ones expected by professors which her 18-yr old classmates “without a whole lot of experience” give them, she says “I think my FoKs actually negatively impact me… this is not the way I learned growing up or at [community college].” With a great sense of frustration, she acknowledges that this process “turns people into tools and not so much into creative thinkers.”

However, her decision to switch majors was not straightforward as it might appear in a transcript. Faith searched deep into her life experiences and FoKs. As a single mother, she had to fight legal battles with the father of her kid over smoking inside the house. This forced her to learn a great deal about indoor pollution, toxins, and physiological reactions to smoke by conducting self-directed research and interacting with a nurse that helped low-income single mothers. In addition, she realized that she has deeper commitments towards understanding the community-environment nexus because of her ongoing work in the community garden that she helped build and her brother runs. In order to secure healthy food for her community, which might be considered a “food desert” with access to just one supermarket, Faith wants to dedicate her efforts in engineering school to understanding those interrelationships between environment (garden, creek), community, and engineered systems (highway, mines). In short, her decision to choose and switch majors, from mechanical and environmental, has been significantly influenced by her FoKs.

FoKs in making it into a major: Jennifer

Growing up in Peru, Jennifer learned about what is perhaps the most prevailing of her FoKs: being resourceful or as Jennifer calls it “fake it until you make it.” First, leaving her parents and neighborhood friends behind, she learned to pretend being in a higher socio-economic class by living in her grandma’s house during the week just to be closer to a private religious school unavailable in her poor neighborhood. In order to get her a scholarship, her non-religious parents pretended to be good Catholics and got married by the church so she could get the scholarship and be admitted to the school. During the weekends and school breaks, Jennifer learned more about being resourceful watching her mom deploy energy saving strategies at home to keep the electricity bill low and exchanging favors in a corner convenience store that her parents own.

Jennifer has deployed her FoK successfully in order to balance the extraordinary demands of her student and work schedule. Jennifer is a single mother of two, holds two jobs away from campus, and two jobs on campus, all this while keeping a GPA of 3.0 in chemical engineering, a major that is viewed as one of the most competitive on campus. For example, in order to have access to the same content from required expensive textbooks that she cannot afford, she bought the international edition of her physical chemistry book for less than $50, borrowed the more expensive version from her TAs, made copies of appendices with all the equations (not available in the international edition), and attached the copied appendices to her less expensive textbook. In Chemical Engineering Thermodynamics, she regularly visits the TA to learn equation tricks (like “grandma hates tomato soup”) and how the professor grades exams even before taking exam. In the first exam, she got 100% and in the final she got a 85 when the class average was 71. As a transfer student, she can no longer take easy electives to increase her GPA, as she brought most of these credits from her community college. Yet she found a way to take a research experience for undergraduates (REU) for credit, where she only has to put the hours in order to get a good grade. In Fluid Mechanics, her most challenging class yet, she got notes from other students and watched videos in youtube, both strategies that helped her pass the class.

At a recent internship with a major chemical engineering company, Jennifer exchanged favors with technicians (who were otherwise skeptical of engineering interns) and even cooked a Peruvian meal for them, in order to solve technical problems under her responsibility. Building these lasting friendships helps her now in school. For example, in Chemical Process Lab, she nailed 20% of the project by calling her friends at the company in order to solve the problem at hand. In a recent campus interview for a very desired internship with BP, the company held a group dinner with the candidates where most of them from more privileged backgrounds displayed cultural and social capital that Jennifer did not have. Most of the applicants talked about having traveled to Europe and having engineers as parents. Jennifer has neither. Yet the next day, she nailed the technical exam on distillation processes given her positive previous experience with the chemical company where she learned much from technicians. She also nailed the behavioral exam where she was able to display her experience holding full-time jobs as a teacher and a care giver. At the end, BP offered her the internship.

FoKs in finding yourself in a major: Javier

Javier is a child of migrant workers from Mexico who came to the US to find work. Wanting to provide better schooling for the kids while in the US by avoiding public schools in poor neighborhoods, his parents constantly moved neighborhoods in order to find private religious schools that could offer them scholarships. Javier's mother was always in charge of figuring out these moves and looking after Javier's education, as his father was too busy making a living for the family by driving and fixing trucks. This created a split life for Javier between academics (a domain managed by his mother) and working on and driving trucks (a domain managed by his father). Javier developed a substantial fund of knowledge of mechanical devices and systems while working on and driving his dad's trucks (e.g., brakes, engines, suspension, compressors, etc.). As a teenager, he even secured a truck commercial driving license. In spite of his preference for and knowledge of all things mechanical, Javier passed on choosing mechanical engineering for the more promising salaries that petroleum engineering (PE) graduates are getting at Mines.

Unlike most undergraduates, Javier cannot afford living in the dorms, so he lives at home with his parents. Javier felt split between connecting with his father through their shared FoK and his coursework in PE, which he could not share with his father, since his father would not understand. In this way, being a PE student made Javier feel isolated from his father and his mechanical FoK, since he was not able to come home every night to discuss his courses or projects in PE with his father, the main source and mentor for his mechanical FoK. The tensions and conflicts of this split life were palpable throughout the interviews leading up to his first petroleum-related internship.

Things changed when Javier got an internship at a natural gas fracking site as part of his PE plan of studies. At the site, he found that his FoK made him able to bridge two sides of the site –data analysis and operations – in ways that no other engineering intern could. At a fracking site, engineers sit in trailers analyzing data while technicians and operators work on the ground driving trucks, pouring chemicals to be pumped underground, and figuring out how to optimize pump performance. The two sides rarely interact, given there is a socio-economic divide that reflects on how each side sees the other. On the one hand, engineers have little respect for operators and view their manual work as trivial and even dirty. On the other hand, technicians have disdain for engineers and view their work as out of touch with the realities and difficulties of getting gas out of the ground. Javier's LIFG background, his mechanical FoK and his growing knowledge of PE allowed him to bridge this rift. He was welcomed and trusted by both sides: in the data analysis trailer, due to his affiliation with a respected engineering school, and by the technicians and operators, due to his knowledge of trucks, pumps, and all things mechanical. The operators were even more impressed that an engineering intern held a commercial driving license and allowed Javier to drive trucks with chemicals at the site. Meanwhile at home, Javier was able to build another bridge by sharing and explaining PE to his dad perhaps for the first time. And at school, in fluid mechanics, perhaps one of the most difficult and abstract class that engineering students take, Javier was invited to share his internship experience with the class and explain how the insights from the site operators allowed him to better understand how pumps in series and in parallel work. The internship experience, combined with his FoKs and formal school work, allowed Javier to find himself in his major.

FoKs in choosing an engineering job: Julie

Julie grew up in a small town in rural southeastern Colorado, a region dominated by farming and ranching. Her father worked as a bricklayer and in construction before working his way into management at a local plant, and her mother ran a beauty salon out of their garage. She and her brother were raised in the same house that her paternal grandparents built to raise their own seven kids before passing it onto their son when his family was growing and they were moving into old age. In addition to raising seven kids and tending a giant backyard garden to feed them all, her grandmother worked three jobs—sewing, babysitting, and working at the pickle plant—to help support the family and her husband's wages from working for the railroad and a grocery store. Even though neither of her parents graduated from college, it was never a doubt in her or her brother's mind that they would since her parents had insisted as such since they were very small.

For Julie, the appeal of engineering was that it would provide a good job and an opportunity to help other people. Both she and her brother ended up at Mines after an engineer at her father's workplace told them that it was the best engineering school. After graduating with a degree in mechanical engineering, she had multiple interviews in varying industries but took a job at an engineering firm that was expanding the public lightrail system in the Denver metro area since the specific qualities of the firm aligned the closest with her vision of a meaningful engineering career. This vision of what engineering should be was firmly grounded in the worldview and FoKs she developed while growing up. Improving public transportation appealed to her intense desire to use engineering to improve the public good rather than simply create profits for a company, and the job provided an opportunity to engage in contextual problem solving and work directly with technicians whose expertise in the physical world was valued by the engineers in the office.

Julie's experiences building, manipulating and fixing tangible things led her to thrive on real-world engineering problem solving. When approaching a problem, she first asks herself what kind of materials are available to solve it, keeping an eye to those that are the most locally appropriate and affordable. She purposefully designed and developed a biosand water filter in the freshman design course to be made out of materials that even the poorest people could easily find in a backyard, that way it could be built, used, and maintained without costly trips to hardware stores for supplies. This emphasis on local and affordable sourcing came from her experiences as a child. For entertainment, her grandmother would take her and her brother to a spot out of town where they could collect clay to then go shape into pots. She also spent hours in the backyard garden with her father, who came up with creative ways to maintain the health of the garden and its produce without using expensive fertilizers, herbicides, and pesticides. For example, she remembered building a mesh contraption out of things they found in his shop in order to filter out the Bermuda grass in the garden.

After assessing the availability of materials, Julie then considers the physical constraints of where the actual system or artifact is going to be built, and how those impact the people doing the work, installation, and maintenance. In her senior design team, she was the most attentive in her group to thinking about the risks their home design posed to the people doing the construction. She convinced them to change their plans for waterproofing the foundation when she realized that they would require someone to work at the bottom of an eight-foot trench that would bury them alive if the dirt collapsed. During her internship at the railroad firm where she eventually took a permanent job, she similarly enjoyed thinking about the real world space limitations of the lightrail, and how its eventual location required not just enough space for the actual rails and cars, but space for people to work on it during installation and maintenance.

Julie's appreciation for the people who do the work of building and maintaining physical structures was cultivated through her own experiences helping her father with "constant remodeling" projects around their house—such as holding up sheet rock and tearing out concrete—and observing and coming to love and appreciate a close-knit group of her father's friends who all helped each other with big projects around their homes. The "bros," as she called them, all worked blue-collar jobs and collectively did all of the maintenance and construction on their homes. The intense ethic of reciprocity that animated their relationships was clear in a story she told about a man who was kicked out of the group. He had long been the subject of critique for not pulling his own weight or being willing to learn a new skill, preferring instead to simply let the more knowledgeable people do the job. The final straw came when he failed to provide food for the group when they were working at his house, attempting to "hide" away from the group and sit and eat separately with his wife and kid. This affront was unacceptable for a group of people accustomed to cooking so much food at well-attended raucous parties that they sent guests home with copious amounts of leftovers.

The affection Julie felt for this big-hearted if gruff group of men translated into her appreciation of the technicians she met as an engineering intern at both a medical devices company and the railway company. Yet the two firm's very different approaches to the knowledge of the technicians convinced her to pay serious attention to how engineers treat laborers and take the job at the railway company, even though the medical device work was more intellectually interesting and challenging for her. She described the divide between engineers and technicians at the medical device company as constituting "segregation," with engineers refusing to lower themselves to visit the manufacturing shop. Powerful statements of class and racial prejudice by the engineers made her extremely uncomfortable as someone whose family made a living in the trades and took pride in their Mexican-American heritage. She made a conscious effort to earn rather than expect the respect of the people in the shop, who had "immediately distrusted" her because she was an engineer. "I went in there asked them what I could do for them," she remembered. To test her, they gave her the job measuring 900 inserts. She meticulously measured each one and entered them into Excel. Then after she also noticed that people were rearranging her pins, she realized that perhaps she had not set up the workspace in a way that made the most sense for them, so she asked them how it should be arranged instead. After she proved she was not above their work and that she appreciated their knowledge, the people started joking with her and teasing her in a caring affectionate way rather than a disparaging way. She had a very different experience working with the railway engineers, who routinely went into the field and laughed and joked and learned from the guys working on the line rather than simply doing engineering from their desks. She described the guys in the field as being "rough, sweaty, cussy, hardworking kinds of guys" who she feels comfortable with since they remind her of her dad's friends. "They're the kind of guys who have calluses on their hands, and short fingernails, like my dad," unlike the students she knew at college who claimed to be engineers but had "baby soft hands." Desiring to be the kind of engineer who learns from people who work with their hands, she took the job at the railway firm, which would give her the opportunity to put her interpersonal skills and respect for technicians' practical knowledge to work.

Future directions for research

Future research in this project will further develop the links between the low income, first generation students' funds of knowledge engineering. Research by a team at Utah State University[14] demonstrates that the funds of knowledge held by working-class Latino adolescents—specifically their values, interests, workplace skills, language skills and experience with household maintenance—can enhance engineering design thinking. Our research also demonstrates that the FoK carried by LIFGs are valuable for engineering design, especially in the context of community development projects that require defining and solving problems in the midst of scarcity, experiential knowledges and skills like those needed in EDfD projects, and desires rooted in empathy with marginalized groups.[15] We are currently investigating the role that recognizing and valuing these FoK play in enhancing students' self-efficacy, which ultimately influences their desires and abilities to complete and succeed in engineering programs. We are also beginning an international collaboration investigating the role of socioeconomic class for teaching and learning about engineering design and community engagement.

The next steps in research on FoK must go beyond simply "recognizing" them to consider how they can be converted into social and cultural capital.[16] Possible steps include mentoring programs between universities and community colleges to help LIFG students transition successfully and a university outreach program to assist LIFGs in enhancing their résumés by highlighting their FoKs and their relevance for engineering and professional skills. We are also developing strategies to bring LIFG FoK into engineering science and design courses, for example, by rewriting engineering problems; collecting and disseminating case studies by LIFG students of how their FoK enhance engineering problem definition, solving and design; and a workshop in which faculty learn how to integrate the case studies—and the practical knowledge carried by LIFGs in general—into their teaching.

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