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The Influence of Connecting Funds of Knowledge to Beliefs about Performance, Classroom Belonging, and Graduation Certainty for First-Generation College Students

Dr. Dina Verdín, Purdue University-Main Campus, West Lafayette (College of Engineering)

Dina Verdín, PhD is an Assistant Professor of Engineering in the Polytechnic School of the Ira A. Fulton Schools of Engineering at Arizona State University. She graduated from San José State University with a BS in Industrial Systems Engineering and from Purdue University with an MS in Industrial Engineering and PhD in Engineering Education. Dina is a 2016 recipient of the National Science Foundation's Graduate Research Fellowship and an Honorable Mention for the Ford Foundation Fellowship Program. Her research interest focuses on changing the deficit base perspective of first-generation college students by providing asset-based approaches to understanding this population. Dina is interested in understanding how first-generation college students author their identities as engineers and negotiate their multiple identities in the current culture of engineering. Dina has won several awards including the 2018 ASEE/IEEE Frontiers in Education Conference Best Diversity Paper Award, 2019 College of Engineering Outstanding Graduate Student Research Award and the Alliance for Graduate Education and the Professoriate (AGEP) Distinguished Scholar Award. Dina's dissertation proposal was selected as part of the top 3 in the 2018 American Educational Research Association (AERA) Division D In-Progress Research Gala.

Dr. Jessica Mary Smith, Colorado School of Mines

Jessica M. Smith is Associate Professor in the Engineering, Design & Society Division at the Colorado School of Mines and Co-Director of Humanitarian Engineering. She is an anthropologist with two major research areas: 1) the sociocultural dynamics of extractive and energy industries, with a focus on corporate social responsibility, social justice, labor, and gender and 2) engineering education, with a focus on socioeconomic class and social responsibility. She is currently completing a book manuscript on the intersection of engineering and corporate social responsibility. She is the author of Mining Coal and Undermining Gender: Rhythms of Work and Family in the American West (Rutgers University Press, 2014), which was funded by the National Science Foundation and National Endowment for the Humanities. In 2016 the National Academy of Engineering recognized her Corporate Social Responsibility course as a national exemplar in teaching engineering ethics. Professor Smith holds a PhD in Anthropology and a certificate in Women's Studies from the University of Michigan and bachelor's degrees in International Studies, Anthropology and Latin American Studies from Macalester College.

Dr. Juan C. Lucena, Colorado School of Mines

Juan Lucena is Professor and Director of Humanitarian Engineering Undergraduate Programs and Outreach at the Engineering, Design & Society Division of the Colorado School of Mines (CSM). Juan obtained a Ph.D. in Science and Technology Studies (STS) from Virginia Tech and a MS in STS and BS in Mechanical and Aeronautical Engineering from Rensselaer Polytechnic Institute (RPI). His books include Defending the Nation: U.S. Policymaking to Create Scientists and Engineers from Sputnik to the 'War Against Terrorism' (University Press of America, 2005), Engineering and Sustainable Community Development (Morgan &Claypool, 2010), Engineering Education for Social Justice: Critical Explorations and Opportunities (Springer, 2013), and Engineering Justice (with Jon Leydens, Wiley, 2018)

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Abstract
First-generation college students in engineering accumulate bodies of knowledge through their working-class families. In our ethnographic data of first-generation college students, we identified tinkering knowledge from home and from work, perspective taking, mediational ability, and connecting experiences as knowledge sources brought to engineering. The purpose of this paper was to understand how first-generation college students' accumulated bodies of knowledge (i.e., funds of knowledge) support their beliefs about performing well in engineering coursework, feeling a sense of belonging in the classroom, and certainty of graduating. Data for this study came from a survey administered in the Fall of 2018 from ten universities across the US. In this study, only the sample of students who indicated their parents had less than a bachelor's degree (n = 378) were used. A structural equation modeling technique was employed to examine several interconnected research questions pertaining to funds of knowledge, performance/competence beliefs, classroom belongingness, and certainty of graduating with an engineering degree. Our analysis demonstrates that the accumulated bodies of knowledge obtained through tinkering at home, tinkering at work, and the skill of being a mediator served to scaffold concepts that students were currently learning in engineering. There was a negative direct relationship between students' ability to make connections between their home activities to scaffold what they are currently learning and their certainty of graduating with an engineering degree. However, first-generation college students' perceptions of performing well in their engineering coursework and their sense of belonging in the classroom positively supported their certainty of graduating thus emphasizing the importance of connecting students' funds of knowledge to engineering coursework and classroom instruction. Implications for possible approaches towards connecting first-generation college students' funds of knowledge to engineering coursework and classroom culture are discussed.

Introduction
Students who are the first in their families to attend college (i.e., first-generation college students) enroll in engineering programs with accumulated engineering-relevant bodies of knowledge from their experiences at home, through their communities or through manual or skilled labor. Often first-generation college students come from backgrounds where they cannot afford or have the option to attend summer engineering camps and are instead working in manual or skilled labor venues [1]. Additionally, the knowledge and skill of first-generation college students may not be that of engineers or scientists, but of working-class families. When these skills and knowledge are not valued in the engineering classroom, it requires first-generation college students to negotiate who they are, where they come from, and who they aspire to be. When this knowledge is not leveraged in the classroom or is even devalued by others (e.g., professors, peers,

and other university staff), it is a missed opportunity for first-generation college students to incorporate their core identities into engineering and to build upon the strengths of their accumulated bodies of knowledge in their active practice of engineering.

It is not a coincidence that first generation college students find their knowledge and skills absent from or devalued inside of the engineering curriculum. Historical research shows that over the past century, engineering education has shifted away from hands-on practice in favor of a standardized sequence of science and math curricula; "practical" education was "systematically pushed out of the four-year curriculum and into two-year community colleges as engineers sought to establish the field as a profession befitting the middle class" [1] also see [2]–[4]. Engineering knowledge is not value neutral and—depending on how it is selected, organized, demarcated, delivered, and evaluated—it can have discriminatory effects on different populations (e.g., [5]–[7]. Often students are implicitly asked to leave aspects of themselves at the door before entering the classroom in order to learn "objective" engineering knowledge [8]. This history of the engineering profession means that class biases were baked into its educational systems, helping to explain why students from low-income and working-class backgrounds describe the culture and content of undergraduate engineering programs as foreign, if not hostile (e.g., [9]).

Critically reflecting on what knowledge "counts" as engineering knowledge is thus important for understanding and better supporting students who are the first in their families to attend college. We assert that the knowledge and skillsets first-generation college students bring with them to engineering should "count," or better yet, when this knowledge and skillsets are recognized as legitimate sources of knowledge, they can serve as capital towards learning engineering and ultimately contribute to these students' success in engineering. Our work uses the funds of knowledge framework to help engineering educators see and build upon the crucial bodies of knowledge that are held by underrepresented students but often not visible inside of classrooms, with the ultimate goal of better supporting these students and their interest and learning in engineering. In the larger scheme, our study is also a call for social justice, as providing opportunities for first-generation college students to view their knowledge as legitimate knowledge is an important step towards equity and inclusion.

Theoretical Framework

Funds of knowledge are the "historically accumulated and culturally developed bodies of knowledge and skills essential for household or individual functioning and well-being" [10, p. 133]. The funds of knowledge framework provides a counter-hegemonic response to pervasive forms of cultural deficit thinking, which view poor and minoritized students' culture as the cause of their educational mishap (see Valencia [11], [12] for a discussion). The funds of knowledge framework uses an asset-based perspective to recognize knowledge that is often ignored [13], [14]. This framework has largely supported primary and secondary educators' efforts to create culturally relevant pedagogical practices by leveraging students' lived experiences (see [15]–[17]. For example, the work of Mejia and Wilson-Lopez [18] captured how Latino/a adolescents leveraged their engineering-related funds of knowledge to create a solution in a design project or in problems faced in their everyday lives. Their study found that high school students' funds of knowledge can be relevant to engineering bodies of knowledge, skills, and habits of mind such as systems thinking, scientific or mathematical knowledge, production and processing [19], [20].

The funds of knowledge in higher education goes beyond *recognizing* students' funds of knowledge to *converting* them into forms of social and cultural capital that can improve the students' wellbeing and transform higher education to be more inclusive [21]. This perspective calls attention to the relationships of power within which engineering students live, including the curriculum, classroom settings, and engineering culture. It disrupts the deficit discourse found in the cultural capital theory and "challenges power structures that reproduce educational inequalities" [21, p. 35]. The work of engineering studies scholars have emphasized how cultural capital has played a significant role in the organization, legitimation, dissemination and use of engineering knowledge around the world, since the creation of engineering schools and professional societies [22]–[25]. Thus, a funds of knowledge approach presses against dominant notions of social and cultural capital by asserting the potential value of the social and cultural capital of non-elite families, while still recognizing that these can be devalued in institutional settings such as engineering programs. Parallels exists between funds of knowledge and social and cultural capital. Oughton [26] argues that both are characterized by "sets of gradually acquired and long-lasting dispositions … manifested in skills, know-hows, and competences" (p. 69). Both funds of knowledge and cultural capital can be transmitted between generations, accumulated, and converted [26], [27]. Through a funds of knowledge perspective, we capture engineering students' lived experiences; understand how their family and community knowledge is produced and transmitted; and then investigate whether and how this knowledge is transformed into capital that serves students' trajectories through their career paths. Recognizing first-generation college students' funds of knowledge and how this knowledge is transmitted into forms of capital to support their engineering career pathway offers a way to position these students experiences as equally valuable knowledge in engineering.

Research Questions

To understand how first-generation college students' funds of knowledge support their engineering career trajectory we used structural equation modeling to examine the following interconnected research questions:

1. Which funds of knowledge do first-generation college students see as connecting with what they are currently learning in engineering?
2. Do first-generation college students' funds of knowledge support their beliefs about understanding engineering content and their perception of classroom belonging?

3. Do first-generation college students' funds of knowledge support their goal of graduating with an engineering degree?

Method

Data for this study came from a survey administered in the Fall of 2018 at ten four-year universities in the United States west, south, and mountain regions, $N = 819$. The purpose of the survey was to understand how first-generation college students leveraged their funds of knowledge in engineering [28]. The institutions were chosen based on purposeful sampling. Five of the participating universities were purposefully selected because they had a support program for engineering students who are the first in their families to attend a four-year university and/or are low-income. These five institutions were an ideal place to maximize our sample of first-generation college students. The other schools were selected because they offered geographic and demographic diversity.

This study focuses exclusively on the sample of first-generation college students (FGCS). Students were categorized as first-generation college students if they indicated their parents' level of education as either "less than a high school diploma," "high school diploma/GED," or "some college or associate/trade degree." While students who reported having one or more parent who completed a ''bachelor's degree'' or ''master's degree or higher'' were removed from further analysis since the study sought to examine the relationship between first-generation college students' funds of knowledge and engineering graduation certainty. **The sample of students who indicated their parents had less than a bachelor's degree (i.e., FGCS) was *n* = 378, which is 46% of the overall sample.** The distribution of FGCS who responded to our survey ranged from 125 (15%) first-year, 157 (19%) second year, 205 (25%) third-year, and 332 (41%) fourth year or higher. Our research questions and analysis focus only on the sample of first-generation college students; additional demographic information about these participants can be found in Table 1.

Table 1 Demographic Information of First-Generation College Students Surveyed in Fall 2018

Race/ Ethnicity	First-Generation College Student (FGCS)	FGCS & Pell Grant Recipients^{+}	Female	Male	Another Gender
Asian	79	50	105	90	0
Black or African American	17	11	19	14	0
Latino/a or Hispanic	181	133	80	146	0
Middle Eastern or Native African	19	14	11	24	0

Native Hawaiian or another Pacific Islander	6	4	5	6	1
Native American or Alaska Native	3	2	3	4	0
White	108	53	194	206	2
Another race/ ethnicity not listed above	1	0	3	1	0

Note. Students were allowed to choose any and all race/ethnicities with which they identified.
+Students were allowed to opt out of answering this question by indicating 'prefer not to answer,' meaning that this column only represents students who indicated they receive Pell Grant.

Survey Measures

The survey items used in this study have shown strong validity evidence in prior work, specifically the latent construct of engineering performance/competence and the single item used to measure sense of belonging in the engineering classroom, i.e., *I feel that I am part of my engineering classes,* [29]–[32]. The six funds of knowledge latent construct used in this study were created using ethnographic data of first-generation college students and validity evidence was obtained using a sample with high representation of first-generation college students (i.e., 46%; [33], [34]. Table 2 provides corresponding definitions of the six funds of knowledge latent constructs used in this study.

Table 2. Definitions for the Funds of Knowledge Latent Constructs

Connecting experiences	Students' ability to draw from hobbies or home environment activities to scaffold what they are currently learning in engineering.
Tinkering knowledge from Home	Tinkering knowledge from home relates to activities (i.e., repairing, assembling, or building) that students have engaged with in their home environment.
Tinkering knowledge from Work	Tinkering knowledge from work pertains to activities (i.e., fixing, assembling, or building) that students have engaged with in a work-related environment, both paid and unpaid (e.g., volunteer-work).
Perspective Taking	A cognitive capacity to examine a situation or examine another person's experience.
Mediational Skills	Students' ability to help others 'sort things out' in unfamiliar situations or circumstances
Reading People	Using non-verbal cues (i.e., body language and emotional state) to understand others or situation.

Analysis

Before the analysis, data was cleaned of indiscriminate responses. To account for missing data, a multiple imputation method with an expectation-maximization bootstrapping technique from the Amelia II package in R was used [35]. A multiple imputation method is more robust than listwise deletion as it reduces bias. Following, data used in this analysis were checked univariate and multivariate normality, and multicollinearity. Before answering our research questions, data were screened to assess whether assumptions of univariate and multivariate normality were violated using skewness, kurtosis, and Mardia's Test. Assumptions of univariate normality were within acceptable ranges of skewness (absolute values within 2.0) and kurtosis (absolute values within 7.0). Mardia's test for multivariate normality revealed that data were not multivariate normal, therefore, a robust maximum likelihood (MLM) estimator was used to correct for non-normality. MLM corrects for both the model chi-square and the standard errors of the parameter estimates for deviations from a normal distribution [36], [37]. Structural equation modeling was used to examine how first-generation college students' funds of knowledge supports their beliefs about being able to perform well and understand engineering content, sense of belonging in the engineering classroom, and certainty of graduating with an engineering degree. The structural equation model was evaluated using the following indexes: chi-square goodness of fit, comparative fit index (CFI; acceptable values above 0.9), Tucker Lewis index (TLI; acceptable values above 0.9), root mean square error of approximation (RMSEA; values less than 0.05 indicate excellent fit, less than 0.08 indicate moderate fit), and standardized root mean square residual (SRMR; acceptable value is less than 1, where 0.0 would indicate perfect fit) [36], [38], [39]. The analysis was conducted using the R programming statistical software version 3.5.3 [40]. The lavaan package was used to run the structural equation model [41].

Results of Model fit

The measurement model was tested using confirmatory factor analysis (CFA). A CFA was conducted separately for all latent constructs to determine how well the survey items measured the intended constructs of tinkering at home, tinkering at work, connecting experiences, perspective taking, mediational ability, and performance/competence beliefs. The Satorra-Bentler adjusted chi-square test for goodness of fit for the six latent constructs was $X^2_{SB} = 547.72$, $df = 260$, $p < .001$. The fit indexes were CFI of 0.95, TLI of 0.94, and RMSEA of 0.05 with CI [0.048 to 0.060] and SRMR is 0.05. Overall, the fit indexes for both models suggest good overall model fit. The CFI and TLI values were above 0.90, values above 0.90 reflect good model fit while values closer to 1 implies "perfect" model fit [36], [42]. The RMSEA is less than .08, indicating acceptable model fit [36], [43]. Brown (2015) notes that additional support for fit using RMSEA is evidence by having a 90% confidence interval upper limit value below 0.08 and our model is below that limit. Lastly, the SRMR value indicates acceptable model fit.

Following, the structural model, outlined in Figure 1 was analyzed using structural equation modeling, the Satorra-Bentler adjusted chi-square test for goodness of fit for the STEM identity constructs was $X^2_{SB} = 611.77$, $df = 310$, $p < .001$. The fit indexes were CFI of 0.95, TLI of 0.94, and RMSEA of 0.05 of with CI [0.048 to 0.056] and SRMR is 0.05. All standardized factor loadings were well above the 0.45 minimum cut off values [44]. Indicator reliability, evaluated by individually squaring the standardized factor loadings were above 0.50 demonstrating that each item measured above 50 percent of the true-score variance (Brown, 2015). The construct reliability, evaluated using Cronbach's alpha, were between 0.82 to 0.96, which are above the recommended alpha value of 0.70, indicating good construct reliability [45]. The amount of variance captured by each construct was greater in relation to the amount of variance due to measurement error, i.e., variance was above 0.50 [46]. All average variance extracted (AVE) values were above the recommended 0.50 value indicating the constructs have convergent validity. A summary of all factor loadings, item reliability, construct reliability, and average variance extracted can be found in Appendix A.

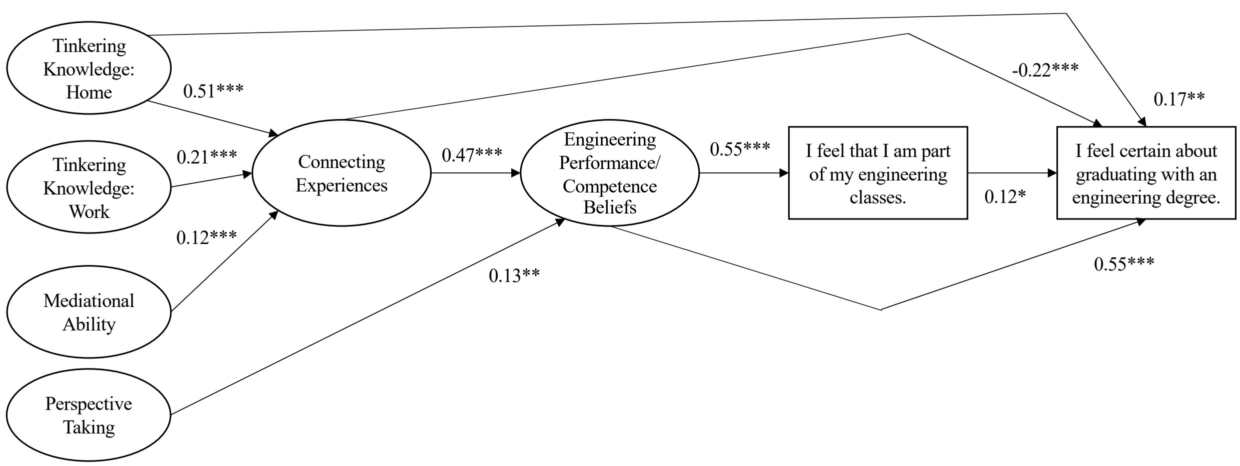

Figure 1. Structural equation model of the funds of knowledge constructs, engineering performance/competence belief, sense of belonging, and certainty of graduating. Non-significant values were removed for parsimony. Note, * $p < .05$, ** $p < .01$, and *** $p < .001$. The covariance for the constructs of tinkering knowledge from home, tinkering knowledge from work, mediational ability, and perspective taking are omitted from this visual but all of these constructs covary. All the indicators for the latent constructs where omitted from this visual, the indicators can be found in Appendix A.

Discussion of Results

In this study, we sought to examine if and how first-generation college engineering students' bodies of knowledge accumulated through home activities, work, and/or community engagement (i.e., their funds of knowledge) are supporting their engineering performance/competence beliefs, sense of belonging in the classroom, and certainty of graduating with an engineering degree. Our first research question asked, *which funds of knowledge do first-generation college students see as connecting with what they are currently learning in engineering?* We used the construct connecting experiences as the bridge to understand if first-generation college students used their knowledge attained from their home or hobby activities to support what they are learning in engineering. The goal was to understand if the funds of knowledge of tinkering knowledge from home, tinkering knowledge from work, mediational ability, perspective taking, and reading people, were leveraged to support students engineering coursework. Results from the model revealed that tinkering knowledge from home ($\beta = 0.51$, $p < .001$), tinkering knowledge from work ($\beta = 0.21$, $p < .001$), and mediational skills ($\beta = 0.12$, $p < .001$) had a direct relationship to the construct connecting experiences, which suggests that these specific funds of knowledge were used to support what first-generation college students were learning in their engineering coursework. The proportion of variance for the construct connecting experiences, explained by tinkering knowledge from home and work and mediational skills was 46.7%, $R^2 = 0.467$. Our survey data thus suggest that first generation college students see connections between their engineering coursework and the skill and knowledge they acquired through home and work related activities (i.e., repairing, assembling, or building) and their abilities to help others 'sort things out' in unfamiliar situations or circumstances. Many of the students in our prior ethnographic research said that their experiences of fixing things around the house helped them understand engineering concepts. For example, the first generation college students in our prior ethnographic work drew on their diverse backgrounds such as plumbing and pumps to understand fluid dynamics (Smith and Lucena 2016). Additionally our results found that two funds of knowledge—perspective taking aptitude (i.e., capacity to examine a situation or examine another person's experience) and the capacity to read people (i.e., using non-verbal cues, body language and emotional state, to understand others or current situation)—did not have a direct connection with what students were learning in engineering (i.e., construct connecting experiences). Perspective taking did, however, have a direct connection with first-generation college students' competence beliefs, as we analyze below.

Next, we sought to understand, *do first-generation college students' funds of knowledge support their feelings that they understand engineering content and that they belong in the engineering classrooms?* The funds of knowledge of perspective taking directly supported first-generation college students' confidence in their abilities to do well in their engineering coursework (i.e., engineering performance/competence beliefs; $\beta = 0.13$, $p < .01$). The funds of knowledge of perspective taking can be understood as a capacity that supports empathic practices, and empathy is an essential attribute engineers should learn and emulate in their practice [47], [48]. Perspective taking, for Julie, a mechanical engineering student in a separate study, was instrumental for her ability to design a biosand water filter with materials that low-income families can find in their own backyards and when designing a waterproofing foundation that took into account the safety of the workers that will be excavating the eight-foot trench (Smith & Lucena, 2015). In the study by Smith and Lucena (2015), Julie's ability to put herself in the shoes of others (i.e., low-income families and labors) supported her engineering design capabilities. The work of Hess et al. (2016) has linked the capacity to take other people's situation/circumstances into account (i.e., perspective taking) to innovative behavioral tendencies of questioning, observing, and experimenting. The leadership literature has also confirmed the importance of the funds of knowledge of perspective taking, noting that this capacity is essential for effective leadership as it supports leaders when working with others to solve problems and implement change [50]. Scholarship supports the importance of perspective taking on the practice of engineering and our study confirms it is especially important for first-generation college students' confidence in their abilities to perform well and understand engineering bodies of knowledge.

In addition to perspective taking, first-generation college students' abilities to draw connections from their home and hobby activities to support their learning in engineering coursework had a strong relationship with their confidence about performing well and understanding engineering content ($\beta = 0.47$, $p < .001$). The proportion of variance for the construct engineering performance/competence beliefs, explained by connecting experiences and perspective taking was 26.9%, $R^2 = 0.269$. First-generation college students' tinkering knowledge from home, tinkering knowledge from work, and their mediational skills did not have a direct effect onto their confidence about performing well in engineering; rather, these funds of knowledge were mediated by students' abilities to see connections with their experiences and the content they are learning in engineering (i.e., connecting experiences). No direct relationship was found from connecting experiences to a sense of belonging in the classroom, which may reflect that their funds of knowledge are not visible to or valued by their peers and professors. Additionally, no direct relationship was found for the funds of knowledge constructs of tinkering knowledge from home, tinkering knowledge from work, mediational skills, perspective taking, and reading people on first-generation college students' feelings of belonging in the classroom. Rather, the model demonstrates the importance of performance/competence beliefs for those connecting experiences to positively impact students' sense of belonging: seeing a connection between first-generation college students' knowledge gained from their experiences and believing that they can perform well in engineering seems to foster belongingness in the classroom (i.e., connecting experiences → engineering performance/competence beliefs → belonging in the classroom). Prior work, using a different dataset, found a strong relationship between first-generation college students' confidence that they can perform well and understand their engineering coursework to their sense of belonging in the classroom [31]. The relationship between engineering performance/competence beliefs and feeling a sense of belonging in the classroom is verified in this study with a high estimate ($\beta = 0.55$, $p < .001$). The proportion of variance for the single indicator *I feel that I am part of my engineering classes*, explained by engineering performance/competence beliefs was 30.6%, $R^2 = 0.306$. The work of Gopalan and Brandy [51] has shown that feeling a sense of belonging differs based on students' demographics; in their study using a nationally representative dataset they found that first-generation college students reported feeling a lack of belongingness in a 4+ year university. While the study by Gopalan and Brandy was not contextualized to engineering students, a sense of belonging seems to have a greater impact on first-generation college students' nationally. Feeling a sense of belonging is a fundamental human motivational factor that supports active engagement and psychological well-being [52], [53]. Our results demonstrate the importance of being able to perform one's competence in engineering to first-generation college students' sense of classroom belongingness.

Current opportunities for first generation college students to connect their funds of knowledge with their engineering coursework may be limited by dominant definitions of what "counts" as engineering knowledge or ways of doing engineering. To date, practical knowledge and work with the hands were systematically defined out of what "engineering" is and how it could be taught and learned, as engineering education became scientized over the course of the 20th century. This history can also be read as one in which the funds of knowledge of working people were defined out of what counted as engineering knowledge and subsequently representation in the classroom setting. The messages students receive about the types of learning experiences or ways of knowing that are valued in engineering can have an effect on their engagement in engineering and ultimately their degree completion. In a study by Benedict et al. [54] and Verdín et al. [33] a first-year engineering student, Anika, described not having traditional engineering-related experiences but spoke about how she thought it was important that her hobby as an artist be connected to engineering, as she stated, "... a lot of engineers aren't really artistic, and so I guess that makes me stand out, which maybe I can help connect to different things that people don't think of" [p. 5]. While Anika, spoke about how her hobby as an artist made her stand out, she also affirmed that this body of knowledge made her *unlike* an engineer [54], it seems this participant is straddling between seeing her experiences as important in engineering and subsequently not having her experiences validated in her engineering course work. Prior work has confirmed that the construct of connecting experiences supports all students (i.e., first-generation and continuing-generation college students) perception of seeing themselves as engineers [34].

Our last research question sought to determine how first-generation college students' funds of knowledge served as capital that could support their success, by asking, *do first-generation college students' funds of knowledge support their goal of graduating with an engineering degree?* Certainty of graduating is based on students' beliefs about graduating, specifically with an engineering degree, obtaining the necessary knowledge to succeed in their career, and obtaining their desired engineering job. We found that only tinkering knowledge from home had a direct effect onto first-generation college students' certainty of graduating ($\beta = 0.17$, $p < .01$). This suggests a powerful relationship that could be better leveraged by engineering educators, as we explain in the next section on practical strategies to build upon this research. Prior work also pointed to the special significance of tinkering knowledge from home, finding that first-generation college students were more likely to see their tinkering knowledge from home as supporting their interest in engineering and beliefs about seeing themselves as engineers when compared to continuing-generation college students [34]. The connection between these funds of knowledge and engineering coursework reveals an important additional finding. In an ethnographic study, Faith, a mechanical engineering student, did not see her funds of knowledge (i.e., acquired through working as a technician in a ski tuning shop, learning about friction, metals, melting points, etc.; working as a cook learning about boiling points; and working on cars and wooden decks) connected to her engineering coursework, which subsequently led her to switch out of mechanical engineering and into environmental engineering, which resonated more with her community gardening experience and ethical commitments surrounding social justice [49]. Faith's account shows that the lack of connection between her experiences and knowledge, on the one hand, and her engineering coursework, on the other, can result in a reevaluation of one's career trajectory. While Faith was able to find congruence with her lived experiences and the engineering bodies of knowledge she was learning, it is difficult to assume other students may find congruence.

The funds of knowledge constructs of tinkering knowledge from work, mediational skills, perspective taking, and reading people were individually regressed onto certainty of graduating with an engineering degree, and none were significant. We conclude that the funds of knowledge tinkering knowledge from work and mediational skills are fully mediated by the construct connecting experiences. First-generation college students' beliefs in their capabilities to understand the content knowledge and perform well had a strong direct effect onto their certainty of graduating with an engineering degree ($\beta = 0.55$, $p < .001$), while a sense of belongingness in the classroom had a mild but significant effect ($\beta = 0.12$, $p < .05$). A negative direct relationship was found between the construct connecting experiences and students' certainty of graduating with an engineering degree ($\beta = -0.22$, $p < .001$); conversely connecting experiences had a positive relationship through two mediational pathways. That is, when first-generation college students draw on their experiences to support what they are currently learning, the knowledge transmitted from these experiences builds their confidence in performing well and understanding engineering content in order to support their certainty of graduating with an engineering degree (i.e., connecting experiences → engineering performance/competence beliefs → I feel certain about graduating with an engineering degree). Likewise, the pathway between connecting experiences, performing well in engineering, and feelings of belongingness in the classroom positively supports certainty of graduating with an engineering degree (i.e., connecting experiences → engineering performance/competence beliefs → belonging in the engineering classroom → I feel certain about graduating with an engineering degree). In the next section we present practical strategies for engineering educators and other student support staff to facilitate those crucial connecting experiences between first-generation college students' funds of knowledge and engineering coursework and classroom culture.

Implications for Practice

Our study clearly reveals the importance of connecting experiences for first-generation college students' performance and beliefs that they can do well in engineering and for feeling certain about graduating with an engineering degree. However, curricular spaces and opportunities for allowing students to have these connecting experiences are scarce in engineering education. However, there might be some opportunities at the *periphery* of the engineering science curriculum where students can connect their funds of knowledge to what they are learning in engineering (e.g., in makerspace clubs, design projects, reflective writing in humanities and social science classes). Yet the *core* of the engineering curriculum (e.g., basic math and sciences and engineering science courses), as well as preceding programs aimed at preparing students for such core curriculum (summer bridge camps, pre-engineering programs at community colleges, preparatory courses, etc.), remain ripe territory for engineering educator reformers to build connecting experiences. For example, instructors teaching pre-engineering courses at community colleges, remedial courses during summer bridge programs, and engineering science courses, can facilitate these connecting experiences by allowing students to re-write and frame math or engineering science problem statements in ways that explicitly incorporate home and workplace tinkering experiences. Using the four-step process for critical engineering pedagogy proposed by Riley [55] to *engage* students taking thermodynamics, teach them to *analyze*, challenge them to *reflect,* and motivate them to *change* current circumstances, engineering instructors can do the same for first-generation college students. One example aimed at understanding of the concept of energy and its units, a key required concept in all thermodynamics courses, could include:

- Asking them to keep a journal for the energy expenditures (in kW) of their home tinkering activities (e.g., use of tools or cooking appliances);
- Teach them to estimate, analyze, and compare those energy expenditures with the energy expenditures of their peers at school (e.g., dorm-room/home energy expenditures or driving to work)
- Challenging them to reflect on what their peers would have to change about their lifestyle to live on 1 kW; and,
- Invite them to change by developing a plan to reduce energy use in the dorms of their university or at home. (see [55, pp. 23–24])

Similar connecting experiences can be developed and deployed in all basic and engineering science core courses (see [56]).

Other funds of knowledge constructs from first-generation college students in engineering can be celebrated, valued and incorporated in different parts of engineering education. For example, the direct relationship between perspective taking (empathy) and students' confidence in their abilities to do well in their engineering coursework can be operationalized in design courses or student organizations. Students' ability to examine a situation and put themselves in another person's shoes (i.e., perspective taking) could be considered a desired characteristic that design project or organization leaders must have in order to be selected. During elections, candidates for president of Engineering Without Borders (EWB) student chapters, for example, will be required to show that they can understand, value and work with different perspectives such as local community members, engineering students, NGO officials, etc. in the definition of a local project. A similar recognition of the importance of perspective taking can be applied to the selection of student leaders for senior design projects. Alfredo an engineering student who is a low-income first-generation college student from Mexico who participated in our previous research, demonstrated this perspective taking in his job as a construction worker where he mediated between the perspectives of engineers, foremen, other construction workers, suppliers, etc. participating in the construction of a sewage pipeline project. Later in engineering school, he was able to position himself as a student leader in a senior design project where he deployed this perspective taking between his team members and all other stakeholders related to the design project.

Makerspaces, in vogue now in most engineering schools yet at the periphery of the curriculum itself, deserve special attention. We speculate that the direct relationship between tinkering knowledge from home and graduation certainty could, in part, be related to recent increased celebration of "making" and makerspaces inside of engineering education. However, we join others in cautioning that while these spaces ostensibly celebrate work with the hands, they are profoundly gendered, raced, and classed environments that can reproduce existing structures of privilege and inequity [57], [58]. Engineering educators and administrators involved in makerspaces could, for example, allow first-generation college students to display perspective taking by teaching other students how certain tools or processes are viewed or used by mechanics ("my dad, a mechanic, taught me that these tools are best used for…") and compare those uses to the ones they are witnessing by peers in the makerspace ("while you are using these tool as…").

Conclusion

In this paper, we demonstrated how first-generation college students' funds of knowledge are important for their confidence in their engineering performance, classroom belonging, and success in graduating with an engineering degree. Our analysis suggests that first generation college students' confidence in their engineering performance, classroom belonging, and graduation certainty could be enhanced by opportunities to connect their varied funds of knowledge to engineering coursework and classroom instruction. Efforts to diversify engineering education remain focused outside the engineering curriculum and efforts focused outside the curriculum have left the actual content of engineering knowledge mostly unexplored and untouched as a site of analysis [59]. Our study emphasizes the importance of connecting experiences as they solidifies students' confidence about performing well in engineering, which in turn solidifies their sense of belonging in the classroom and their certainty of graduating with an engineering degree. We presented practical strategies for engineering educators and other student support staff to facilitate those crucial connecting experiences between first-generation college students' funds of knowledge and engineering coursework and classroom culture.

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Appendix A

Table 4 Results of Confirmatory Factor Analysis for the Funds of Knowledge Latent Constructs

First-Order Latent Construct / Survey Items	Std. Fac. Loadings	*SE*	Item Reliability	α	AVE
Tinkering Knowledge: Home				0.91	0.71
Q4a = At home, I learned to use tools to build things.	0.850	0.07	0.723		
Q4b = At home, I worked with machines and appliances (considered broadly, e.g., gym equipment, sewing machines, lawn mower, bikes, etc.).	0.795	0.08	0.632		
Q4c = I learned to fix things around the house (considered broadly, e.g., plumbing, furniture, electrical wiring, etc.)	0.862	0.07	0.743		
Q4e = At home, I learned to assemble and disassemble things.	0.860	0.07	0.740		
Tinkering Knowledge: Work				0.96	0.81
Q5a = At work, I learned to work with tools	0.928	0.06	0.861		
Q5b = At work, I learned to use tools to build things.	0.931	0.06	0.867		
Q5c = At work, I worked with machines (e.g., car jack, sewing machine, lawn mower, etc.).	0.832	0.07	0.692		

Q5d = At work, I learned to fix things.	0.914	0.06	0.835		
Q5e = At work, I learned to assemble and disassemble things.	0.892	0.06	0.796		
Connecting Experiences				0.80	0.50
Q3a = I see connections between my **hobbies** and what I am learning in my engineering coursework (e.g. design projects, homework, exams, presentations).	0.671	0.06	0.450		
Q3b = I see connections between experiences at **home** and what I am learning in my engineering courses.	0.637	0.07	0.37		
Q3c = I draw on my previous experiences from my **hobbies** when little instruction is given on how to solve an engineering task.	0.779	0.07	0.62		
Q3d = I draw on my previous experiences at **home** when little instruction is given on how to solve an engineering task.	0.724	0.08	0.61		
Perspective Taking				0.82	0.62
Q6a = I am open to listen to the point of view of others.	0.822	0.06	0.74		
Q6b = I consider other people's point of view in discussions.	0.865	0.05	0.61		
Q6d = I like to view both sides of an issue.	0.666	0.06	0.77		
Mediating Ability					
Q8a = Help someone else adjust to an unfamiliar place.	0.770	0.06	0.60	0.90	0.65
Q8b = Help someone else adjust to unfamiliar social situations.	0.800	0.07	0.86		

Q8c = Help different groups of people better understand each other better.	0.848	0.07	0.88		
Q8d = Bring people together in the same space who usually would not spend time with each other.	0.803	0.07	0.64		
Q8e = Help different individuals on a team better understand each other.	0.783	0.06	0.74		
Engineering Performance/Competence Beliefs					
Q10k = I am confident that I can understand engineering in class.	0.888	0.06	0.789	0.88	0.65
Q10l = I am confident that I can understand engineering outside of class.	0.794	0.06	0.630		
Q10m = I can do well on exams in engineering.	0.730	0.07	0.532		
Q10n = I understand concepts I have studied in engineering.	0.831	0.05	0.691		

Note. α = construct reliability; AVE = average variance extracted