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Funds of Knowledge as Pre-College Experiences that Promote Minoritized Students' Interest, Self-Efficacy Beliefs, and Choice of Majoring in Engineering

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Keywords

funds of knowledge, engineering interest, self-efficacy, mediation analysis

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Abstract

Pre-college experiences both inside and outside of the classroom inform students' interest in science, technology, engineering, and mathematics (STEM)-related activities, help them evaluate their knowledge and skills in various tasks, and shape their perceptions of themselves as individuals who can participate in STEM. Yet little empirical research examines the valuable pre-college knowledge, practices, and skills that minoritized students acquire through their home experiences and how they can support students' transition into an engineering pathway. This study addresses this gap by investigating how students' funds of knowledge support their interest in engineering, self-efficacy beliefs, and certainty of pursuing an engineering major. Data for this study came from a diverse group of first-year engineering students. A serial mediation analysis confirmed that first-year students' tinkering knowledge from home supports their beliefs about doing well in their engineering coursework, which in turn helps their certainty of majoring in engineering. Seeing a connection between experiences at home and what is being taught in engineering coursework and the ability to draw from home experiences to solve an engineering task supported minoritized students' self-efficacy beliefs, interest, and certainty of majoring in engineering. Our study demonstrates how diverse first-year engineering students' everyday household knowledge and skills serve as assets for pursuing an engineering degree. Practical strategies are discussed to promote minoritized students' funds of knowledge (i.e., tinkering knowledge from home, perspective taking, and mediational skills) to science practices and the engineering design process outlined in the Next Generation Science Standards.

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Introduction

Broadening participation in engineering is a call for access. Students need to be provided with opportunities to become engaged with science, technology, engineering, and mathematics (STEM) concepts, which may be achieved through innovative teaching and learning approaches, particularly at the K-12 level. Efforts to robustly incorporate engineering into the science curricula continue to make headway, as noted in a recent call to build teacher capacity (National Academies of Sciences Engineering and Medicine, 2020). Incorporating engineering education into K-12 teaching and learning, through the Next Generation Science Standards (NGSS), opens the doors for diverse students who may otherwise struggle to make connections between their home lives and the figured world of science and engineering (e.g., Calabrese Barton, 2003;

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Carlone et al., 2015; Costa, 1995) and can serve as a pathway towards choosing an engineering career. The implementation of the NGSS offers an opportunity to broaden the participation of minoritized students into engineering career pathways, as "engineering has the potential to be inclusive of students who have traditionally been marginalized in the science classroom and do not see science as being relevant to their lives or future" (NGSS Lead States, 2013). Support to implement engineering in the K-12 curricula responds to the need to provide real-world context to math and science courses, which subsequently helps prepare students to solve 21st-century problems and gain authentic learning experiences (National Research Council, 2012). Additionally, research studies have documented the benefits of introducing engineering concepts in K-12 education as a mechanism to bolster students' interest in STEM subjects and engineering career interest (Apedoe et al., 2008; Becker & Park, 2011; Cantrell et al., 2006; Miller et al., 2020).

We contribute to these growing efforts by demonstrating that minoritized students' pre-college experiences and practices from home or their everyday lives are sites where interest in engineering can be fostered and engineering self-efficacy beliefs can be nurtured. We contend that minoritized students' home practices are informal learning experiences that can complement and supplement school-based engineering and science education, and that this view of students' backgrounds can be especially important for supporting students who come from working-class families, low-income communities, and families in which parents may not have advanced formal training. These families have accumulated household bodies of knowledge, practices, and experiences that can serve as tools of engagement towards adolescents' choice to pursue an engineering major. Paying attention to engineering students' pre-college home experiences is vital because these are places where engineering interest is triggered, and confidence in their abilities to understand engineering is cultivated. Therefore, we took a retrospective approach and examine how one specific element of minoritized first-year engineering students' pre-college experiences—their accumulated bodies of knowledge from home, i.e., their funds of knowledge (González et al., 2005)—supports their engineering interest, self-efficacy beliefs, and commitment towards pursuing an engineering degree. Our study provides valuable insight into how minoritized students' practices of making connections between their home experiences and their formal education can support their interest in engineering and decision to pursue an engineering major. We write from a standpoint that minoritized students' home lives are rich sources of knowledge and experiences that can support engagement in the engineering figured world. We conclude by returning to the NGSS' efforts to offer educators concrete strategies to leverage minoritized students' funds of knowledge to create asset-based approaches to meet those standards.

Background

Research has shown that students' choice to pursue an engineering major is driven by (1) experiences during their high school years, (2) high school academic preparation, (3) development of self-efficacy beliefs and interest, and (4) out-of-school learning experiences. In a study using data from the National Education Longitudinal Study tracking students from eighth grade through their mid-twenties (i.e., while in college), Maltese and Tai (2011) found that over half of students majoring in STEM reported choosing their major during high school. Another study examining trends of students' intention to pursue an engineering career found that 37% of students became interested in engineering at the beginning of high school, and 81% became interested at the end of high school (Cass et al., 2011). Warne and colleagues' (2019) study of over fifteen thousand students found that Advanced Placement (AP) Calculus participation was strongly associated with a career interest in engineering. Attributing the uptick in students' interest in majoring in STEM at the end of high school due to AP courses in mathematics and science offered in students' junior and senior years is also supported by other scholars (Mattern et al., 2011; Potvin et al., 2009; Wai et al., 2010; Warne et al., 2019).

However, high school experiences are contingent upon resources and structures afforded to students, and not all students have equal access to these resources. For example, the experiences afforded to well-funded high schools or students with family members knowledgeable of the college process are different from those afforded to students from low-income neighborhoods or whose family members did not navigate the college curriculum. A longitudinal study of students in middle school to the transition into college found that parental level of education was predictive of students taking mathematics and science courses in high school and college (Svoboda et al., 2016). A report documenting the national participation in AP courses found that while more high schools offer students college-level preparation, low-income students (identified using free/reduced lunch as a proxy) were three times less likely to be enrolled in these advanced preparatory courses (Theokas & Saaris, 2013). The unequal opportunities in advanced science and mathematics courses disproportionately affect racial/ethnic minority and low-income students (see Riegle-Crumb & Grodsky, 2010; Rodriguez & McGuire, 2019; Solórzano & Ornelas, 2002).

While advanced preparatory mathematics and science courses are viewed as mechanisms for triggering students' interest in engineering careers, there is considerable evidence that shows both in- and out-of-school learning experiences also influence career choices (Godwin, Sonnert et al., 2016; Miller et al., 2020; Ozis et al., 2018; Phelps et al., 2018; Verdín, Godwin, Sonnert et al., 2018). Students' self-efficacy beliefs and interest support their choice of pursuing an engineering degree (Cribbs et al., 2016; Godwin, Potvin et al., 2016; Ketenci et al., 2020; Lent et al., 2008, 2013). Longitudinal studies have demonstrated that pre-college learning experiences and math self-efficacy are predictive of postsecondary STEM degree completion (Bettencourt et al., 2020) and engineering persistence (Lee et al., 2015). High school learning experiences, both in and out of the classroom, benefit students' decision to pursue an engineering major in college. Maltese and Tai (2011) identified students' interests and abilities as motivating factors towards pursuing a STEM degree. Chan et al.'s (2020) longitudinal study affirmed that participation in informal learning experiences promoted students' STEM self-efficacy beliefs, interest, and academic performance and that access to informal learning experiences is not equitably accessible. Their study underscored that Latinx students, from both low-socioeconomic (SES) backgrounds and high-socioeconomic backgrounds, were less likely to have participated in math and science out-of-school experiences compared to their White peers. Dabney et al. (2012) also found that students from high-SES backgrounds were more likely to participate in out-of-school clubs and competitions than students from low-SES backgrounds. Collectively, this research suggests that while out-of-school activities benefit students' decision to pursue an engineering major, the opportunities to participate in such activities are not equitably available to minoritized students.

Given the inequities of common pathways into engineering, traditional forms of out-of-school experiences may not be the answer for low-income and racially/ethnically diverse students. We propose that this opportunity gap can be bridged by understanding and treating their everyday experiences as learning settings. This approach resonates with the National Research Council's (2009) call to leverage students' everyday experiences and local environments as starting points to help bridge cultural and home practices to learn science, and, we add, to learn engineering content. Existing research points to the promise of leveraging minoritized students' funds of knowledge to enhance their interest and confidence in engineering. Wilson-Lopez et al.'s (2016) ethnographic study of adolescent Latinx students found that the household and community knowledge students drew upon to solve a community-based engineering design problem mapped onto "engineering design processes, systems thinking, ethical and empathetic reasoning, knowledge production and processing, use of communication and construction tools, scientific and mathematical knowledge, and teamwork" (p. 278), which are all connected to engineering habits of mind. Similarly, the work of Mejia et al. (2014) found that three Latino adolescents used their lived experiences and household and community knowledge to help brainstorm solutions to an engineering design challenge. While the three students in Mejia et al.'s (2014) study had access to "iPads, internet, and the expertise of two engineers" (p. 14), they chose to rely on their own lived experiences and knowledge of their family or community members to tackle the design challenge. These studies underscore how students used their knowledge—obtained through their lived experiences, households, and communities—to approach an engineering design challenge. Additionally, both authors documented a positive shift in students' beliefs in their capabilities to use their knowledge to solve an engineering design problem (Mejia et al., 2015).

Scholars in the science education space have similarly used students' lived experiences and personal interests as mechanisms towards supporting learning and engagement. Basu and Calabrese Barton (2007) found that low-income students were more engaged and sustained interest in science when they could leverage their personal experiences and knowledge to make science relevant and meaningful. Calabrese Barton and Tan (2009) documented the benefits of incorporating funds of knowledge into the science class in a low-income middle school and found that engagement (i.e., contributing to class discussions and turning in assignments) increased when students were able to connect their home experiences with the science unit. Bouillion and Gomez (2001) also found that connecting science with students' everyday life experiences enhanced students' sense of efficacy and interest in science. Taken together, students' household knowledge and lived experiences are essential tools educators can use to support learning and interest in scientific and engineering-related content.

Therefore, in light of prior research, we know that connecting students' lived experiences and household knowledge to STEM-learning can support STEM-related domain interest and self-efficacy beliefs. Building upon this understanding, we sought to examine how minoritized students leverage their pre-college household knowledge and experiences to support their choice of pursuing an engineering degree. Our work contributes to the growing body of literature that promotes minoritized students' household knowledge and lived experiences as rich sites for learning. We take a retrospective approach towards understanding how the pre-college funds of knowledge of first-year, minoritized engineering students support their engineering interest, self-efficacy beliefs, and desire to pursue an engineering degree.

Theoretical Framework: Funds of Knowledge

The funds of knowledge framework was originally envisioned as a heuristic device to guide teachers to discover and engage students' existing knowledge, home experiences, and practices to build connections between households' repertoire and the classroom curriculum. This framework defines funds of knowledge as "historically accumulated and culturally developed bodies of knowledge and skills essential for household or individual functioning and well-being" (González et al., 2005, p. 72). It is based on a conception of culture not as "shared norms that shape individuals' behavior…[or]…standardized rules of behavior," but as *practice*, that is, "what it is that people do, and what they say about what they do" (González et al., 2005). This distinction is important because prior educational research wrongfully faulted minoritized students' culture as the cause of their educational mishap (Valencia, 1997), partially based upon a view of culture as a "holistic configuration of traits and values" that narrowly shaped students' perspective (González et al., 2005; Gutiérrez & Rogoff, 2003). In contrast, a processual approach to understanding students' culture allows for multiple perspectives and focuses on everyday lived experiences. These daily activities and practices can then be analyzed and celebrated as "a manifestation of particular historically accumulated 'funds of knowledge'" (González, 1995).

The funds of knowledge framework is an asset-based approach that challenges the implicit (and explicit) deficit view that ethnic minority students come from households and communities that are poor in terms of knowledge and quality of experiences (Moll et al., 1992). It provides a counter-hegemonic response to pervasive forms of cultural deficit thinking by using an asset-based perspective to recognize students' everyday knowledge, practices, and experiences that are often ignored in the classroom (González et al., 2005; Rios-Aguilar et al., 2011). This approach disrupts the discourse surrounding minoritized students (e.g., low-income, first-generation college students, and racial/ethnically minoritized students) and provides a necessary intervention into how educators should think about the students they teach. Through a funds of knowledge lens, lived experiences are treated as sources of valuable knowledge, and a family's knowledge, social networks, and resourcefulness are emphasized as assets that can be leveraged in students' learning (González et al., 2005).

Research demonstrates that incorporating students' funds of knowledge into science and mathematics curricular units benefits student engagement and domain-specific interest development (Basu & Calabrese Barton, 2007; Bouillion & Gomez, 2001; Calabrese Barton & Tan, 2009; Irish & Kang, 2018; Walkington et al., 2015; Walkington & Bernacki, 2015). Likewise, enabling students to use their funds of knowledge to solve an engineering design challenge also resulted in a positive shift in their capabilities to apply their knowledge to solve an engineering problem (Mejia et al., 2015). We extend the research on funds of knowledge by investigating how students' household knowledge and practices influence the types of educational pathways they choose. Treating students' funds of knowledge as meaningful pre-college experiences opens a window from which to analyze how funds of knowledge can foster engineering dispositions and, in turn, prompt students to choose to pursue an engineering degree.

Minoritized Engineering Students' Funds of Knowledge

The funds of knowledge lens has primarily been treated as a tool for primary and secondary educators to recognize and leverage their students' household and community practices. Our approach, however, emphasizes that students themselves also have agency to capitalize on their bodies of knowledge to support their learning. Marquez Kiyama and Rios-Aguilar's (2017) work prompts us to acknowledge that students' funds of knowledge are internalized and transmitted to capital when students leverage their practices, experience, and skillsets in their adult lives. Additionally, Oughton (2010) acknowledges the shift from children drawing on their *household* funds of knowledge to young adults and adults drawing on their *own* knowledge, practices, experiences, and skills. The ethnographic interview data of low-income, first-generation college students of Smith and Lucena (2016a, 2016b) exemplify the transmission of adolescences' funds of knowledge into their undergraduate education and engineering internships. When our students in the ethnographic study could connect their funds of knowledge to their engineering studies, they excelled in their coursework, design projects, engineering internships, and jobs (Smith & Lucena, 2016a, 2016b).

Our recent work examining the lived experiences of six low-income first-generation college students found common funds of knowledge across participants that were instrumental in their engineering coursework, internship, and career pathway. For this study's purpose, we focus on three specific funds of knowledge identified in our prior work: tinkering knowledge from home, perspective taking, and mediational skills (Verdín et al., 2021). Our previous study details how the hands-on household skillsets students gained as adolescents—their tinkering knowledge—served as sources of knowledge in their current engineering coursework or internships. Tinkering knowledge from home encompasses skills and practices of building things, fixing things, assembling, and disassembling everyday home items. Yet we also found that there were bodies of knowledge that were less manual and more interpersonal or metacognitive, but still relevant for their engineering practice; this is because there are more to design projects than narrow technical tasks. Perspective taking and mediational skills represent two of these more cognitive funds of knowledge. Our prior work identified metacognitive skills that were instrumental to our participants' trajectory, in line with Oughton's (2010) recognition of a wider set of funds of knowledge (i.e., interpersonal and metacognitive skills) that is relevant to adult learners.

Perspective taking, defined as students' cognitive capacity to examine a situation or examine another person's experience, was prevalent in first-generation college students' growing up experiences. This fund of knowledge acknowledges that hands-on practices afford students the opportunity to gain empathic skills that allow them to reflect on situations around their community or home lives. One participant, for example, spent her childhood learning to listen to the experiences shared by her father and his friends when working on home improvement projects. Later, during her senior design course, she used her perspective-taking skills to create more culturally appropriate homes for Native communities and to critique the danger of a preliminary planning for waterproofing a foundation. Perspective taking is therefore a key fund of knowledge that engages others' viewpoints when undertaking the engineering design process (Verdín et al., 2021).

Our interview data also revealed students' willingness and capability to help others navigate unfamiliar situations—what we call mediational skills—while doing work-related activities (Verdín et al. 2021). Minoritized students actively tried to bring people together with different opinions and served as bridges towards reconciling gaps in work-related practices. Many of our students spoke about how, as engineering interns, they helped reconcile differences between technicians and the management teams, from construction sites to factories (Verdín et al., 2021). They learned how to do so from growing up watching and sometimes working alongside their parents, such as one student who went to worksites with his electrician father and spoke with him at length about the necessity of bridge-building to overcome disconnects in educational and cultural backgrounds. This participant's ability to help others "sort things out" when in an unfamiliar situation at work allowed the technicians and upper management to successfully move forward with the design project. Thus, mediational skills were an important fund of knowledge that minoritized students used in their internships and engineering coursework.

Minoritized students' funds of knowledge encompass discrete knowledge, practices, and experiences and consist of students actively leveraging their repertoire to support their engineering coursework and engineering-related work experiences. Thus, at the core of the funds of knowledge framework is the idea that students enter classrooms with lived experiences that have led to knowledge gains (González et al., 2005). Identifying discrete funds of knowledge (i.e., tinkering knowledge from home, perspective taking, and mediational skills) is important for understanding how educators can incorporate minoritized students' lived experiences into the classroom setting. Equally important is knowing if students were leveraging their specific funds of knowledge to support their engineering learning. Thus, in addition to the funds of knowledge constructs listed above, we developed a survey construct (i.e., connecting experiences) to understand if students explicitly recognized and applied their accumulated bodies of knowledge in their engineering coursework. The connecting experience construct is in line with the more recent shift that focuses on minoritized students' funds of knowledge when transitioning from secondary education to higher education (e.g., Marquez Kiyama & Rios-Aguilar, 2017; Oughton, 2010). These three discrete funds of knowledge and connecting experiences are not exhaustive, and scholars working in this area have identified multiple funds of knowledge held by minoritized students (see Oughton, 2010; Wilson-Lopez et al., 2016). Nevertheless, they do provide the building blocks for investigating how some funds of knowledge may support these minoritized students' decision to pursue engineering.

Hypotheses

Students' interest and self-efficacy influence their choice to pursue an engineering degree; interest and self-efficacy are shaped by experiences both in and out of the classroom. Yet, little is known about how minoritized students' knowledge, practices, and experiences from home may support their decision to pursue an engineering major. We believe that students' household knowledge and practices are influential pre-college experiences that supported their decision to pursue an engineering degree. Using a sample of first-year engineering students, we sought to test the following hypotheses:

H1. Minoritized students' household knowledge, practices, and experiences (i.e., funds of knowledge) will support their interest in engineering, foster self-efficacy beliefs, and contribute to their choice to pursue an engineering major.
H2. Seeing connections between experiences at home and engineering coursework will sustain minoritized students' interest in engineering, their confidence in their abilities, and certainty of choosing engineering.
H3. Minoritized students' ability to leverage their home experiences to scaffold their engineering learning will reinforce their self-efficacy beliefs and support their conviction to pursue engineering.

We used cross-sectional data of first-year engineering students to investigate our hypotheses. First-year engineering students have self-selected into an engineering major; therefore, understanding the impact that students' funds of knowledge had on certainty to pursue engineering, we can identify practices for secondary educators to promote an engineering career pathway.

The first hypothesis is a retrospective examination of how the funds of knowledge minoritized students may have acquired before college supported their decision to enroll in an engineering program. We test the relationship between students' funds of knowledge and certainty of choosing engineering individually and through two mechanisms (i.e., interest and self-efficacy beliefs). Research has found that the development of interest and self-efficacy support students' decision to pursue a STEM degree (Hinojosa et al., 2016; Lent et al., 2008; Marra et al., 2009). Interest and self-efficacy beliefs are complementary motivational variables; their relationship evolves based on the students' phase of interest (Renninger, 2010; Renninger et al., 2014). When interest is well-developed, students are more likely to feel secure about their abilities in the respective area of interest (Renninger, 2010); therefore, interest precedes self-efficacy in our model.

The second hypothesis tests whether students' funds of knowledge supported their certainty of majoring in engineering. In the second hypothesis, our goal is to understand if minoritized students can identify connections between their home experiences (broadly speaking, their funds of knowledge) and if the act of identifying connection solidifies their choice to pursue an engineering degree. The last hypothesis tests if minoritized students capitalize on their funds of knowledge to learn engineering and the benefits capitalizing on their lived experiences has on their certainty of majoring in engineering. Hypotheses two and three are not limited to one particular form of knowledge, experience, or practice from home but instead investigate the relationship between *having* funds of knowledge and *capitalizing* on one's funds of knowledge.

Method

Participants

The data for this study came from a survey administered to engineering undergraduate students from ten institutions across the United States in the west, south, and mountain regions in fall 2018 ($n_{\text{total}} = 819$). The purpose of the survey was to understand how first-generation college students leveraged their funds of knowledge in engineering (Smith et al., 2019). A purposeful sampling technique was employed to maximize the number of engineering students who identified as low-income and/or first-generation college students. We selected five of the participating universities 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. Therefore, our sample may not represent the student population in the regions but is intended to focus on a minoritized student sample. In this study, only the sample of students that indicated they were enrolled as first-year engineering students were used ($n_{\text{first-year}} = 115$). A summary of the first-year engineering students' demographic information can be found in Table 1. This sample of students is uniquely diverse as 46% identified as first-generation college students, 45% identified as receiving Federal Pell Grant, 61% identified their race/ethnicity as non-White, and 50% identified as women. Therefore, the discussion of our analysis is centered around the lived experiences of non-majority first-year engineering students. Lastly, we provide information about students' employment activities prior to attending college. When asked if they had had a paid or unpaid job at any point in time, 72% of our sample of first-year engineering students indicated they had a paid job in the past, while 6% indicated they had an unpaid job. Thus, this underscores the importance of acknowledging that funds of knowledge could have also been derived through students' experiences as young working adults.

Table 1
Demographic information of sampled first-year engineering students.

	Sample total	**First-generation college students**	**Continuing-generation college students**
	115	53 (46%)	63 (55%)
Gender			
Female	58 (50.4%)	20 (38%)	23 (37%)
Male	56 (48.7%)	33 (62%)	38 (60%)
Another gender[a]	1 (0.9%)	0 (0%)	1 (2%)
Race/ethnicity[b]			
Asian	34 (30%)	15 (28%)	19 (30%)
Black or African American	5 (4%)	2 (4%)	3 (5%)
Latino/a or Hispanic	39 (34%)	30 (57%)	9 (14%)
Middle Eastern or Native African	3 (3%)	2 (4%)	1 (0.9%)
Native Hawaiian or another Pacific Islander	0 (0%)	0 (0%)	0 (0%)
Native American or Alaska Native	1 (0.9%)	0 (0%)	1 (2%)
White	45 (39%)	7 (13%)	38 (60%)
Pell grant recipients			
Yes	47 (41%)	35 (66%)	12 (19%)
No	63 (55%)	15 (28%)	48 (76%)
Do not wish to disclose[c]	5 (4%)	3 (6%)	2 (3%)
Held a paid or unpaid job			
Yes—paid	83 (72%)	34 (64%)	49 (75%)
Yes—unpaid	7 (6%)	2 (4%)	5 (8%)
No	25 (22%)	17 (32%)	8 (12%)

[a]Students in this category preferred to be identified as transmasculine. [b]Students were allowed to choose any and all race/ethnicities with which they identified. [c]Students were allowed to decline to state whether they received a Federal Pell grant.

Analysis

We used serial multiple mediation analysis, which allows for "simultaneous mediation by multiple variables" (Preacher & Hayes, 2008) to understand the mechanisms that support students' funds of knowledge onto their certainty of choosing an engineering major. Mediation analysis expands the relationship between an independent variable (X) and a dependent variable (Y) by introducing mediational mechanisms. In mediation analysis, researchers are interested in establishing whether an independent variable can influence a dependent variable both directly and indirectly through a mediator (M; Hayes, 2013). A direct relationship is the outcome of the dependent variable (X) onto (Y) while holding a mediator variable constant. Indirect relationships are the combined influence of X on Y through M. Estimates passing through a mediator should be understood as paths (i.e., X—>M—>Y) and are the product of X's support on M and M's support on Y. Indirect relationships are quantified by the product of path a and path b or the product of the serial mediation (i.e., path a, d, and b; where path d represents the product of two mediators). We used two mediation variables (i.e., interest and self-efficacy beliefs) in our serial multiple mediation analysis. To evaluate if an indirect relationship was significant, percentile bootstrap confidence intervals, using 10,000 bootstrap cases, were used; this is a widely recommended method for assessing inferences about indirect relationships (Hayes, 2018a; Hayes & Scharkow, 2013). Percentile bootstrapping "functions as an empirical approximation of the sampling distribution of the indirect [relationship]"; when confidence intervals do not cross zero, the researcher can claim, with credence, that the indirect relationship is significant (Hayes, 2009). Lastly, our approach to mediation analysis does not adhere to the Baron and Kenny method. Hayes (2009, 2018b, 2018a) and Preacher and Hayes (2008) articulated that evidence of a simple association between X and Y is no longer a requirement for testing a mediation.

We controlled for the influence of parental level of education, socioeconomic status, identifying as a male, and belonging to a race/ethnic group overrepresented in engineering (i.e., White or Asian). Controlling for these variables allows us to understand if the modeled relationships are confounded due to belonging to an overrepresented group, by identifying as a male, not from a low-income background, or having parents with advanced degrees. Four control variables were created; the coding scheme was 1 and 0. Students who reported their parent(s) level of education as greater than or equal to bachelor's degree were coded as 1, all else were coded as 0. Students who reported that they did not receive Federal Pell grant were coded as 1; students who reported receiving a Pell grant or who declined to say were coded as 0. Students who identified as male were coded as 1; students who identified as female or another gender different from male or female were coded as 0. Students who reported identifying as White or Asian were coded as 1, signifying membership in a group overrepresented in engineering; all other races/ethnicities were coded as 0.

Before conducting the serial mediation analysis, we examined assumptions of multivariate outliers and univariate normality. Mahalanobis distance was used to detect multivariate outliers, and we removed one case. Univariate normality was within the acceptable range determined by skewness (values plus or minus 2) and kurtosis (values plus or minus 7; Curran et al., 1996; Muthen & Kaplan, 1992). To evaluate the adequacy of the multiple mediation models, multicollinearity and casewise diagnostics were examined to identify influential cases that were biasing each model. Multicollinearity was examined by evaluating each predictor variable's correlation matrix, the variance inflation factor (VIF), and tolerance statistic. The correlation matrix of all predictor variables did not exceed 0.80. All VIF values were less than 5, and tolerance was above the recommended 0.1 cutoff value (Craney & Surles, 2002; Menard, 2002). We evaluated casewise diagnostics by examining the standardized residuals and Cook's distance for each model. Standardized residuals were compared against a 3.29 z-score value to determine cases that bias the model; we removed cases above the acceptable value to minimize bias. We used Cook's distance to measure the overall influence of cases on each model; all values were below 1 (Cook & Weisberg, 1982).

Our analysis was conducted using R programming language and statistical software system version 3.5.3 (R Core Team, 2019) using the *process* package version 3.5 (Hayes, 2018a). All results reported are in standardized form.

Survey Instruments

The survey items used in this study come from a funds of knowledge scale developed from the lived experiences of low-income, first-generation college students studying engineering (Verdín et al., 2021). Three funds of knowledge survey constructs were used in this analysis: tinkering knowledge from home, perspective taking, and mediational skills. Tinkering knowledge from home is related to activities (i.e., repairing, assembling, or building) that students engaged in within their home environment. For this construct, students were asked to rate their level of agreement, from strongly disagree to strongly agree. Perspective taking is understood as students' capacity to examine another person's situation, experience, or point of view. To understand if students engaged in perspective taking, they were asked to rate how accurate the following perspective taking-related items described them using a scale of not likely to extremely likely. Lastly, mediational skills are defined as students' tendency to help others sort things out in unfamiliar situations or circumstances. To understand if students engaged in mediational practices, they were asked "At any point in your life, how likely were you to have done the following" using a scale of not at all likely to extremely likely.

The survey items corresponding to each construct can be found in Table 2. Tinkering knowledge from home, perspective taking, and mediational skills all had a Cronbach alpha reliability score above 0.83, which meets the recommended reliability threshold (Tavakol & Dennick, 2011). We created composite scores for tinkering knowledge from home, perspective taking, and mediational skills by taking the sum of the values and dividing by the total number of survey items.

The two survey items under the construct connecting experiences capture the movement from merely having funds of knowledge to applying those funds of knowledge. We did not create a composite score for the connecting experience construct to obtain a more granular understanding of the distinction between identifying (i.e., "*I see connections…*") and leveraging (i.e., "*I draw on…*") students' funds of knowledge. To answer the second hypothesis, we used the survey item, "*I see connections between experiences at home and what I am learning in my engineering courses.*" This survey item allowed us to understand if first-year engineering students bridged their home experiences with engineering courses and the influence that bridging had on their certainty of majoring in engineering. To answer the third hypothesis, we used the survey item, "*I draw on my previous experiences at home when little instruction is given on how to solve an engineering task*" to examine if students were not only identifying their home experiences but were actually capitalizing on their experiences to support their engineering learning. The two items were part of the larger survey instrument of students' funds of knowledge, and the process for developing and gathering evidence of validity for the items can be found in prior work (Verdín, Smith, & Lucena, 2019; Verdín et al., 2021).

A composite score was created to capture students' self-efficacy beliefs of doing well in engineering using three items: "*I am confident that I can understand engineering in class*," "*I am confident that I can understand engineering outside of class*," and "*I can do well on exams in engineering.*" The items for engineering self-efficacy follow Bandura's (2006) guidance of phrasing the items in terms of "can do" judgment of an individual's capability to achieve or carry out a domain-specific performance (p. 308). The engineering self-efficacy beliefs items were previously developed and tested using a diverse group of engineering students (i.e., first-generation college students, continuing-generation college students, women, to name a few; Godwin & Kirn, 2020; Verdín, Godwin, Kirn et al., 2019; Verdín Godwin, Kirn et al., 2018) and were borrowed for this study. Responses for the items about engineering interest were based on students' level of agreement, measured using a seven-point anchored number scale ranging from 0—"strongly disagree" to 6—"strongly agree." Cronbach's alpha reliability score for engineering interest was 0.89, meeting the recommended reliability threshold (Tavakol & Dennick, 2011).

Students' engineering interest was captured using a composite score of three items: "*I am interested in learning more about engineering*," "*I enjoy learning engineering*," and "*I find fulfillment in doing engineering*." The composite score for engineering interest corresponds with students' "personal disposition that develops over time in relation to a particular topic or domain and is associated with increased knowledge, value, and positive feelings" (i.e., individual interest; Hidi & Harackiewicz, 2000, p. 152). The survey items for engineering interest have been used in prior modeling work in engineering and science (Verdín, Godwin, Kirn et al., 2019; Verdín Godwin, Sonnert et al., 2018) and were borrowed for the present study. Responses for the items about engineering self-efficacy were based on students' level of agreement, measured using a seven-point anchored number scale ranging from 0—"strongly disagree" to 6—"strongly agree." Cronbach's alpha reliability score for engineering self-efficacy was 0.91.

Table 2
Funds of knowledge survey items used in this study.

Construct	**Survey items used to create composite score**	**Rating scale**
Tinkering knowledge from home	• At home, I learned to use tools to build things. • At home, I worked with machines and appliances (considered broadly, e.g., gym equipment, sewing machines, lawn mower, bikes, etc.). • I learned to fix things around the house (considered broadly, e.g., plumbing, furniture, electrical wiring, etc.). • At home, I learned to assemble and disassemble things.	Seven-point anchored numeric scale ranging from 0—"strongly disagree" to 6—"strongly agree"
Perspective taking	• I am open to listen to the point of view of others. • I consider other people's point of view in discussions. • I like to view both sides of an issue.	Seven-point anchored numeric scale ranging from 0—"very inaccurately" to 6—"very accurately"
Mediational skills	• Help someone else adjust to unfamiliar social situation. • Help different groups of people better understand each other. • Help different individuals on a team understand each other better.	Seven-point anchored numeric scale ranging from 0—"not at all likely" to 6—"extremely likely"
Connecting experiences	• I see connections between experiences at home and what I am learning in my engineering courses. • I draw on my previous experiences at home when little instruction is given on how to solve an engineering task.	Seven-point anchored numeric scale ranging from 0—"not at all likely" to 6—"extremely likely"

Lastly, we used a single measure to examine students' certainty of majoring in engineering: "*I feel sure about my choice of engineering as a major*." Response for this item was measured on a seven-point anchored numeric scale ranging from 0—"not at all" to 6—"very much so."

Limitations

We must acknowledge that minoritized students' lived experiences afford them vast repertoires of knowledge, practices, and skills. Our study only captured a fraction of the bodies of knowledge students hold. Nevertheless, the knowledge, practices, and skills emphasized in this study serve as examples of the impact students' repertoires have on their decision to pursue an engineering major.

Results

Seeking to understand how minoritized students' funds of knowledge supported their decision to pursue an engineering major, we investigated if and how their household knowledge, practices, and experiences fostered engineering interest, self-efficacy beliefs, and certainty of choosing an engineering major. Our study is a retrospective approach examining how minoritized first-year students' pre-college funds of knowledge support their engineering interest, self-efficacy beliefs, and commitment to pursuing an engineering degree.

The control variables (i.e., students whose parents had higher education degrees, high socioeconomic backgrounds, male, and White or Asian), in the five models, were not significant. That is, these groups of students were not more likely to be interested in engineering, did not have higher self-efficacy beliefs, and did not feel more certain of majoring in engineering when compared to their counterparts. Therefore, the discussion of our results centers on minoritized students' funds of knowledge and its influence in choosing an engineering major. In the subsections that follow, we describe the results of each hypothesis. The full results of the four models can be found in Appendix A.

H1. Minoritized students' household knowledge, practices, and experiences (i.e., funds of knowledge) will support their interest in engineering, foster self-efficacy beliefs, and contribute to their choice to pursue an engineering major

Numerous research studies confirm the importance of interest and self-efficacy beliefs on students' decisions to pursue STEM degrees (Hinojosa et al., 2016; Lent et al., 2008; Maltese & Tai, 2011; Renninger et al., 2015) and our results corroborate prior findings, specifically that interest and self-efficacy beliefs support minoritized students' choice to pursue an engineering major: $b_{11} = 0.36$, $p < .000$ and $b_{12} = 0.38$, $p < .000$ respectively. Relatively less is known about how household knowledge, practices, and skills support interest, self-efficacy beliefs, and career certainty. We examine three domains of household knowledge and practices—tinkering knowledge from home, perspective taking, mediational skills—that supported minoritized students' choice to pursue an engineering major.

Our results confirm that tinkering knowledge from home significantly supports minoritized students' certainty of choosing an engineering degree ($c_1 = 0.32$, $p < .001$, 95% CI = 0.11, 0.44; see Figure 1, Model 1). We found that tinkering knowledge from home supports minoritized students' interest in engineering ($a_{11} = 0.40$, $p < .000$), but does not directly support their engineering self-efficacy beliefs ($a_{12} = 0.00$, $p < .968$). When mediated by interest, tinkering knowledge also supports minoritized students' certainty of pursuing an engineering major ($a_{11}b_{12} = 0.14$, 95% bootstrap CI = 0.03 to 0.28). That is, students developed an interest in engineering as a result of the experiences of assembling and disassembling everyday household items before college and, in turn, this practice and interest development supported their certainty of choosing to major in engineering. There was no significant indirect relationship between the combined paths of tinkering knowledge from home, self-efficacy beliefs, and certainty of choosing engineering ($a_{12}b_{12} = 0.001$, 95% bootstrap CI = -0.07 to 0.06). However, when considering the path between tinkering knowledge from home and, the two mediating variables (interest and self-efficacy beliefs) onto students' certainty of choosing an engineering degree, we find a significant serial mediational relationship ($a_{11}d_{11}b_{12} = 0.10$, 95% bootstrap CI = 0.03 to 0.19). Students become interested in engineering as a result of their home experiences of tinkering with household items. Their interest fosters a belief in their capability to understand engineering (i.e., self-efficacy) and their self-efficacy beliefs support their conviction to pursue an engineering major.

Next, we analyzed how students' perspective-taking funds of knowledge supported their certainty of majoring in engineering (Figure 1, Model 2). When controlling for demographic variables we found that perspective taking has a significant relationship with students' certainty of choosing an engineering major ($c_2 = 0.26$, $p < .007$, 95% CI = 0.11, 0.70). Similar to the previous model, engineering interest and self-efficacy had a significant relationship with students' certainty of choosing engineering: $b_{21} = 0.36$, $p < .000$ and $b_{22} = 0.38$, $p < .000$ respectively. Additionally, we found that students' engineering interest was triggered through their perspective-taking capabilities ($a_{21} = 0.34$, $p < .000$), but students' perspective-taking capabilities did not significantly influence their engineering self-efficacy beliefs ($a_{22} = 0.01$,

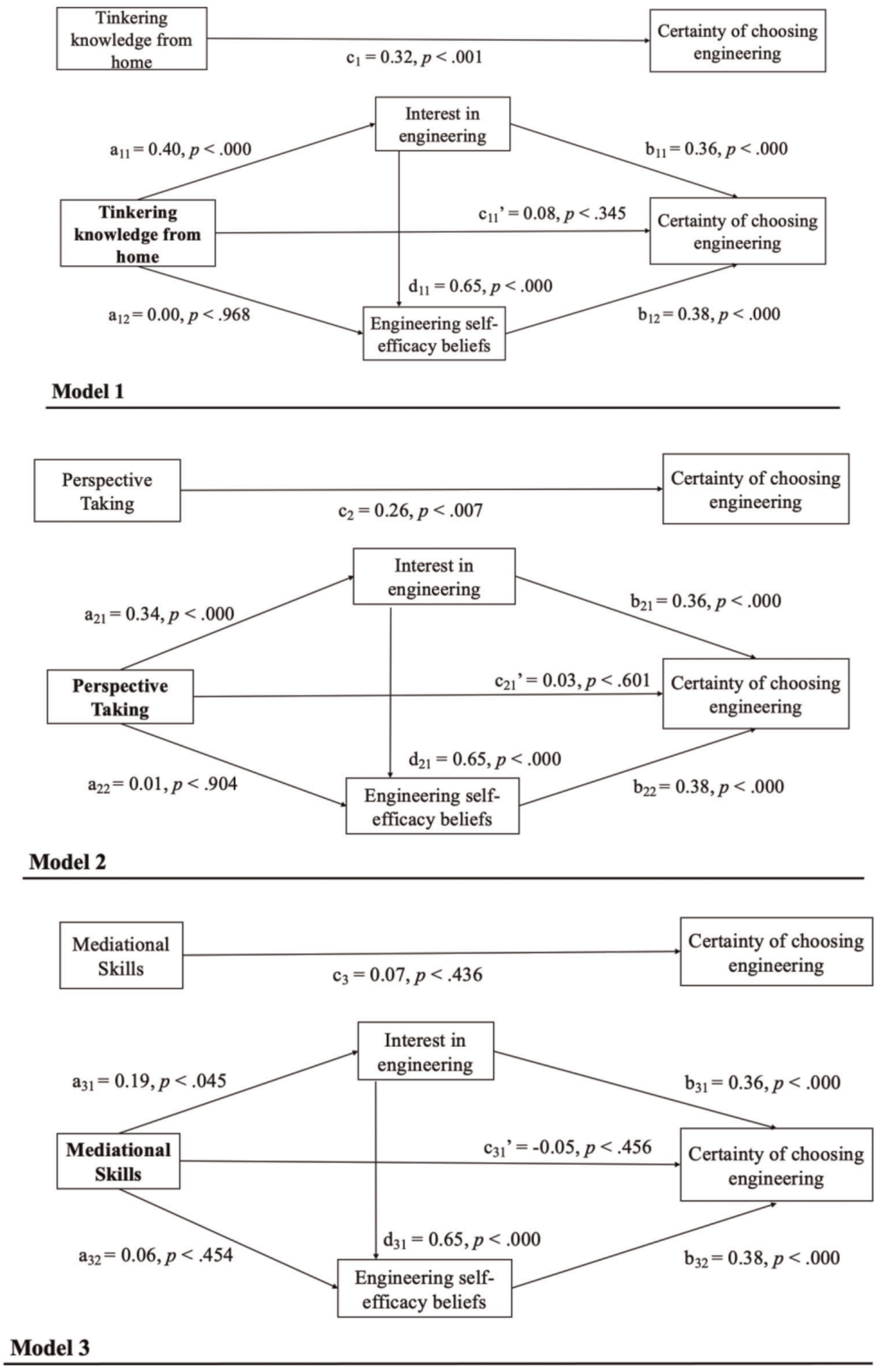

Figure 1. Conceptual diagram of three serial mediation models, modeling the relationship between students' funds of knowledge and their certainty of choosing an engineering major. Values reported are standardized estimates. Control variables are not represented in the diagram but can be found in Appendix A.

$p < .904$). When considering interest in engineering as a mediator between perspective taking and certainty of choosing engineering, we find a significant indirect relationship ($a_{21}b_{21} = 0.20$, 95% bootstrap CI = 0.02 to 0.17). Conversely, when considering students' self-efficacy beliefs as a mediator between perspective taking and certainty of choosing engineering, we find no significant indirect relationship ($a_{22}b_{22} = 0.02$, 95% bootstrap CI = −0.05 to 0.10). The *combined* pathway between perspective taking, self-efficacy beliefs, and certainty of choice was not significant. However, when considering the influence of two mediators (i.e., interest and self-efficacy beliefs), we find that students' perspective-taking ability significantly supports their certainty of choosing an engineering major ($a_{21}d_{21}b_{22} = 0.08$, 95% bootstrap CI = 0.03 to 0.16).

Lastly, we examined the influence of students' mediational skills on their certainty of choosing an engineering major. Students' mediational skills did not directly support certainty of choosing engineering, ($c_3 = 0.07$, $p < .436$, 95% CI = 0.44, −0.13; see Figure 1, Model 3). However, Hayes (2009, 2018a) affirms that there could still be a significant combined relationship between multiple variables when a total relationship is not supported. A mediational analysis allows researchers to evaluate whether an intermediary mechanism supports the relationship between an independent and dependent variable, regardless of a statistically significant association. Therefore, we tested if there was an indirect relationship between mediational skills and students' certainty of choosing an engineering major through interest and self-efficacy. Students' mediational skills had a significant relationship with interest in engineering ($a_{31} = 0.19$, $p < .045$); as well, the combined pathway between mediational skills, interest, and certainty of choice was significant ($a_{31}b_{31} = 0.07$, 95% bootstrap CI = 0.01 to 0.17). There was no significant relationship between mediational skills and self-efficacy beliefs ($a_{32} = 0.06$, $p < .454$); nor was there a significant relationship in the combined pathway of mediational skills, self-efficacy beliefs, and certainty of choice ($a_{32}b_{32} = 0.01$, 95% bootstrap CI = −0.05 to 0.06). When considering the influence of two mediators (i.e., interest and self-efficacy beliefs), we found that students' practice of helping others "sort things out" significantly supports certainty of choosing an engineering major ($a_{31}d_{31}b_{32} = 0.05$, 95% bootstrap CI = 0.01 to 0.10).

In all three models, minoritized students whose parents' level of education was less than a bachelor's degree (coded as 0) were significantly more likely to be certain about their choice of pursuing an engineering major (standardized estimate = −0.18, $p < .038$, 95% CI −0.88 and −0.03) compared to students whose parents held college degrees (coded as 1). To conclude, our analysis affirms that minoritized students' funds of knowledge of tinkering knowledge from home, perspective taking, and mediational skills are especially important towards sustaining their interest, fostering self-efficacy beliefs, and certainty to choose an engineering major.

H2. Seeing connections between experiences at home and engineering coursework will sustain minoritized students' interest in engineering, their confidence in their abilities, and certainty of choosing engineering

Our results in Models 1 through 3 confirm that students' funds of knowledge support their certainty of choosing an engineering major directly and indirectly through interest and self-efficacy beliefs. Thus, we can conclude that students' funds of knowledge served as pre-college experiences that fostered interest in engineering and confidence in their abilities to understand engineering, in line with scholars who have long argued that minoritized students' home experiences were rich sites where learning occurred (González et al., 2005; Moll et al., 1992; Rios-Aguilar & Marquez Kiyama, 2012). Yet, we sought to understand if students were capitalizing on their pre-college funds of knowledge once they were enrolled in an engineering program. The following model (i.e., in Figure 2) analyzed whether students explicitly made connections between their home experiences and their engineering learning.

The ability to recognize those connections, without taking into account mediating variables and controlling for demographic variables, yields no significant total relationship with students' certainty of majoring in engineering (Figure 2; $c_4 = 0.17$, $p < .082$). However, students' ability to see connections between their home experiences and the learning taking place in their engineering courses did support their self-efficacy beliefs ($a_{42} = 0.15$, $p < .048$) even though it did not directly support their interest ($a_{41} = 0.18$, $p < .062$). We found that the *combined* pathway between students' ability to see connections between their home experiences, engineering coursework, and interest supported their certainty of choosing engineering ($a_{41}b_{41} = 0.07$, 95% bootstrap CI 0.001 to 0.17). Likewise, the combined pathway of students' ability to connect their home experiences and their self-efficacy beliefs also significantly supported students' certainty of choosing engineering ($a_{42}b_{42} = 0.06$, 95% bootstrap CI 0.003 to 0.12). Put simply, the sequence of seeing connections between home experiences and engineering learning fosters students' self-efficacy beliefs, and together these support their certainty of majoring in engineering. The serial mediation relationship of interest and self-efficacy beliefs also yields a significant relationship between students' ability to connect their home experiences to their learning and certainty of choosing engineering ($a_{41}d_{41}b_{42} = 0.04$, 95% bootstrap CI 0.001 to 0.10). We can conclude that seeing connections between experiences at home and engineering learning alone is not enough to solidify their major choice. Instead, identifying connections between home experiences and engineering learning needs to be further reinforced with sustained interest and self-efficacy beliefs together to support their certainty of majoring in engineering.

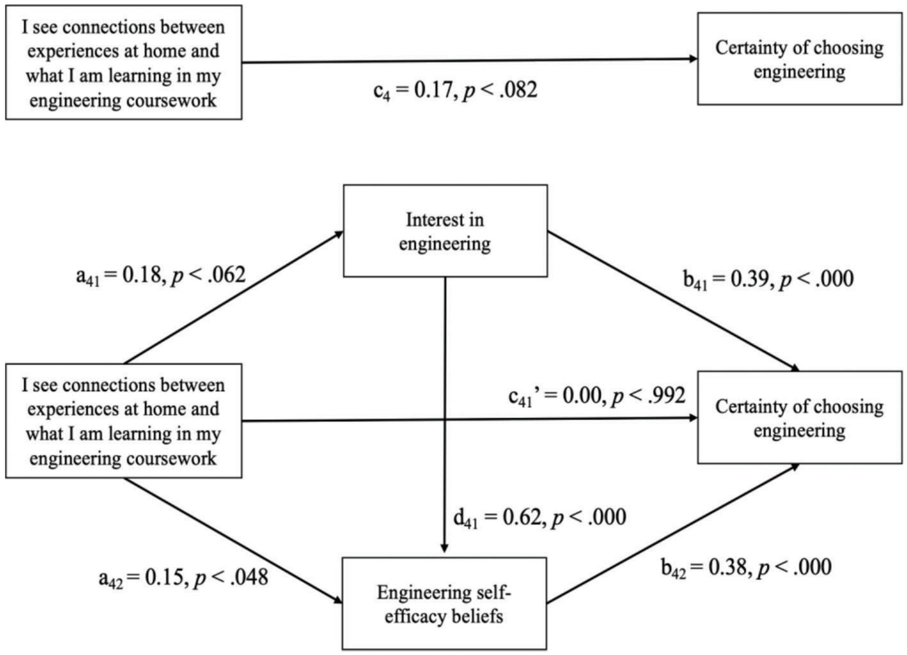

Figure 2. Conceptual diagram of a serial mediation modeling the relationship between connecting experiences at home to support learning in engineering and certainty of choosing an engineering major. Values reported are standardized estimates. Control variables are not represented in the diagram but can be found in Appendix A.

H3. Minoritized students' ability to leverage their home experiences to scaffold their engineering learning will reinforce their self-efficacy beliefs and support their conviction to pursue engineering

Students' ability to identify connections between their home knowledge and the learning taking place in their engineering coursework is thus important for triggering interest, fostering confidence in their performance abilities, and maintaining a commitment towards their choice to pursue engineering. Equally important is understanding if students are *capitalizing* on their pre-college lived experiences to support their engineering learning. We found that minoritized students' ability to leverage their home experiences to scaffold their engineering learning significantly supports their certainty of pursuing an engineering major when no mediation variables are considered (Figure 3; $c_5 = 0.23$, $p < .018$). Students' ability to use their experiences at home when little instruction is given on how to solve an engineering task supported their interest development ($a_{51} = 0.21$, $p < .024$) and bolstered confidence in their ability to understand engineering concepts ($a_{52} = 0.15$, $p < .044$). There was a significant mediational pathway between students' ability to leverage home experiences to scaffold their learning, interest in engineering, and certainty of choice ($a_{51}b_{51} = 0.08$, 95% bootstrap CI 0.01 to 0.17). Likewise, the combined pathway between drawing on experiences at home, self-efficacy, and certainty of choice was also significant ($a_{52}b_{52} = 0.05$, 95% bootstrap CI 0.01 to 0.11). We conclude that minoritized students' capacity to use their experiences from home when little instruction is given on how to solve an engineering task contributes to their certainty of choosing engineering directly and indirectly through their interest and self-efficacy beliefs.

Discussion

Minoritized students enter classroom spaces with lived experiences that carry knowledge, skills, and practices they can leverage to support their interest, confidence, and choice of an engineering major. Scholarship emphasizes that effective learning strategies should be crafted from the learners' existing skills and prior knowledge, and that learning that occurs outside of school should be leveraged in informal settings (National Academies of Science Engineering and Medicine, 2018). Students' education can no longer be solely driven by the activities and knowledge inside the classroom. Deep learning can occur across multiple settings, and students' activities, experiences, and engagement outside the classroom "directly affects what is possible inside the classroom" (National Research Council, 2015). Our study makes several significant contributions to scholarship and practice in this area.

First, the findings illustrated in Figures 2 and 3 confirm that minoritized students' confidence in their abilities to do well in engineering increases when they can see connections between their home experiences and leverage these experiences in their learning. Thus, our study calls attention to the positive impact students' lived experiences have in bolstering

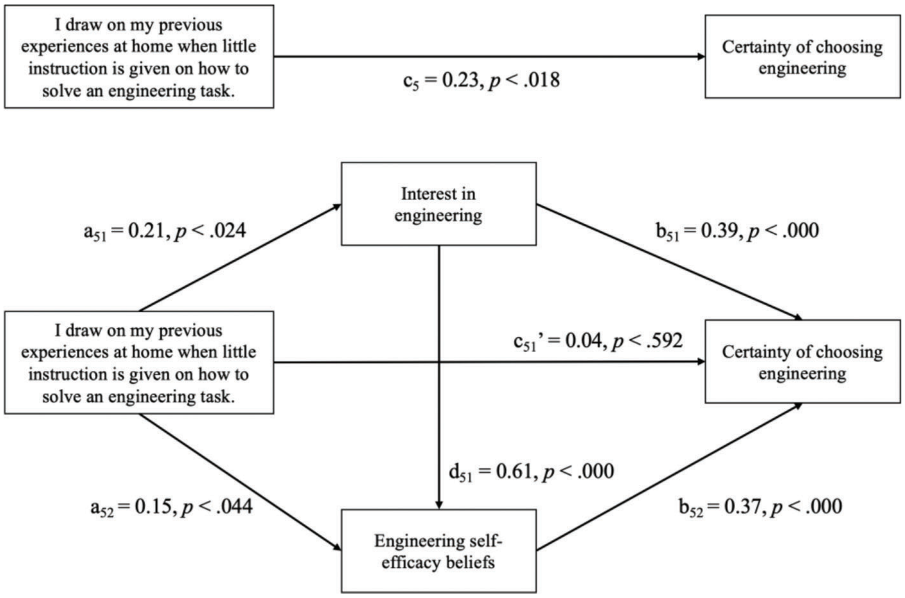

Figure 3. Conceptual diagram of a serial mediation modeling the relationship between leveraging home experiences to scaffold learning in engineering and students' certainty of choosing an engineering major. Values reported are standardized estimates. Control variables are not represented in the diagram but can be found in Appendix A.

confidence in their capability to perform well in engineering. Self-efficacy is an essential component for students' academic performance (Lent et al., 1986, 2008, 2013), persistence in engineering (Bettencourt et al., 2020), and identification as someone that can do engineering (Verdín & Godwin, 2018). In the classroom setting, educators should provide opportunities for students to practice leveraging their home bodies of knowledge to scaffold their engineering learning.

Second, our findings demonstrate that students' funds of knowledge benefit minoritized students' interest in engineering. We found that students' interest in engineering was maintained through the bodies of knowledge they acquired in their tinkering knowledge from home, perspective-taking capability, and mediational skills (Figure 1), and when they were able to draw on their experiences to support their learning (Figure 3). This finding is important because interest development is a powerful motivational force that influences students' decisions to engage and reengage in activities or domain-specific content (Hidi & Harackiewicz, 2000; Renninger & Hidi, 2016; Renninger et al., 2014). Interest is a critical motivational affective state (Hidi, 2006), and "tends to have long-lasting effects on a person's knowledge and values" (Ainley et al., 2002; Hidi, 1990). Renninger and Hidi (2016) also affirm that interest is triggered and maintained when the learner is in an environment that is supportive of their developing interest. Bouillion and Gomez (2001) argue that learning is influenced by day-to-day lived experiences and learning environments can serve as bridging scaffolds where students' life experiences are connected to classroom content.

Maltese and Tai (2011) and Hinojosa et al. (2016) both affirmed that interest motivates enrollment in STEM degrees and that STEM achievement cannot be divorced from interest or efficacy in one's ability. Our study furthers these findings by documenting the positive influence of minoritized students' funds of knowledge on their interest, confidence, and decision to major in engineering. In the three models depicted in Figure 1, students' interest in engineering was facilitated through their experiences of tinkering at home, their perspective-taking capability, and their acquired skills of helping others' sort things out. Engineering self-efficacy, alone, did not have a significant intermediating relationship between students' funds of knowledge and certainty of choosing engineering (i.e., paths $a_{12}b_{12}$, paths $a_{22}b_{122}$, and paths $a_{32}b_{32}$ in Figure 1). Instead, the relationship between minoritized students' funds of knowledge and certainty of choosing engineering was mediated through the combined, sequential influence of interest and self-efficacy beliefs. Educators can support the development of engineering interest and self-efficacy beliefs by providing a space where students from diverse backgrounds can leverage their prior knowledge from home to actively construct an understanding of engineering design principles or habits of mind. That is, creating activities in the classroom that generate funds of knowledge can help bridge the opportunity gap most minoritized students' encounter. For example, the practical hands-on activities of taking apart or assembling household objects should be celebrated in the classroom as learning experiences, and these interest-triggering activities can expose students to engineering ways of thinking. Engineering ways of thinking encompasses the design process and engineering habits of mind (i.e., "systems thinking, creativity, optimism, collaboration, communication, and attention to ethical considerations"; National Academy of Engineering and National Research Council, 2009, p. 5). Students engaging in tinkering with household items are reverse engineering (or dissecting a design solution). They are exploring how and why components were configured in a particular sequence. The knowledge acquired through this form of engagement facilitates an understanding of the engineering design process, where by taking apart a product or reassembling a product students are evaluating the design solution, evaluating how the design of the product was carried out, and analyzing how they would have approached the design. The engineering design process is fundamental to an engineer's knowledge and practice, and engineering habits of mind are also fundamental skillsets that promote engineering literacy (National Academy of Engineering and National Research Council, 2009).

Third, our study also underscores that students' interpersonal capacities (what we analyzed here as perspective taking and mediational skills) are also crucial for developing interest in engineering. Perspective taking is linked to innovative behavioral tendencies of questioning, observing, and experimenting (Hess et al., 2016). The leadership and management scholarship also confirms the importance of the funds of knowledge of perspective taking. Northouse (2016) noted that an individuals' capacity to consider other peoples' points of view is essential for effective leadership as it supports leaders when working with others to solve problems and implement change. Perspective taking is an important component for emotionally intelligent leadership, as studies demonstrate that an individual's perspective taking capability cultivates cooperative behaviors (Parker & Axtell, 2001), enhances team communication (Park & Raile, 2010), amplifies creativity in team settings (Hoever et al., 2012), and is an essential aspect of empathy (Park & Raile, 2010; Parker & Axtell, 2001). Lastly, over 100,000 U.S. companies have emphasized that the most critical assets employers seek are communication skills, a positive attitude, and the competency to work effectively in teams (Millennial Branding and Experience Inc., 2012). Scholarship supports the importance of perspective taking on the practice of engineering. Our study confirms it is especially essential for the development of interest and students' certainty to choose an engineering major.

Finally, our results confirmed that mediational skills also supported students' interest in engineering and their certainty of choosing engineering. The literature identifies mediation skills as a problem-solving process with underlying components such as actively listening, the ability to summarize and reframe a problem, conflict management, and the capability to build positive rapport (Boulle et al., 2008; Doherty & Guyler, 2008). Mediation has been also identified as a necessary workplace skill that can enhance "workplace well-being, cooperation, and productivity" and an important skillset a manager or team leader should have (Doherty & Guyler, 2008). Interpersonal abilities such as mediational skills and perspective taking are often not thought to be at the forefront of an engineers' practice or repertoire. Yet, the Accreditation Board for Engineering and Technology Inc. (ABET) describes the "ability to communicate effectively with a range of audiences" as an essential outcome of a students' preparation (ABET, 2019). Moore et al.'s (2014). *Framework for Quality K-12 Engineering Education*–a framework "intended for educators, researchers, and policy makers to use as a tool for informing the integration of engineering within their educational systems" (p. 4)–invites K-12 engineering educators to allow students the ability to practice communication skills similar to those embodied by engineers. Our findings also confirmed that students may not be identifying mediational skills as essential for an engineer's performance, evidenced in the lack of significant relationship between their funds of knowledge and engineering self-efficacy beliefs. This finding offers an area of opportunity for K-12 engineering educators to provide awareness to students' that engineering literacy encompasses a wide range of knowledge, practices, and skillsets. Engineers have a social and moral obligation to the communities their design solutions serve and to the impact these solutions can have on the environment. The skillset of mediating can help engineers ground their design solutions with an understanding of the impact the solution may have on a community or environment. In the next section we provide strategies for practitioners to leverage students' funds of knowledge while adhering to the performance expectations set forth by the NGSS.

Strategies to Connect Students' Funds of Knowledge to Engineering

A recent call to build capacity to prepare K-12 teachers to teach engineering has made timely the need to provide practical strategies to bridge engineering with students' funds of knowledge (see National Academies of Sciences Engineering and Medicine, 2020). Ainley and Ainley (2015) affirm that for interest to be more than short-lived, students need to see connections between their experiences and the content taught in class. Students' knowledge of tinkering, perspective taking, and mediational skills are instrumental skillsets necessary for the engineering design process and engineering habits of mind. Therefore, to conclude, we offer some practical strategies for connecting students' funds of knowledge to engineering through the NGSS. The NGSS outlines engineering design performance expectations for students based on grade-bands. To provide support in making NGSS more culturally inclusive, we offer strategies that educators can utilize to bridge students' funds of knowledge (i.e., tinkering knowledge from home, perspective taking, and mediational skills) to science practices and engineering design.

Connecting Funds of Knowledge to the NGSS Earth and Space Sciences: Human Impact

Students in middle school and high school are expected to understand the impact human activities have on Earth and the interdependencies between humans and the rest of the Earth. The performance expectations of MS-ESS3-3 require that middle school students "apply scientific principles to design a method for monitoring and minimizing human impact on the environment" (NGSS Lead States, 2013). As part of this learning expectation, students can be asked to identify a household appliance or device and understand its life cycle. Students can be asked to disassemble the appliance or device, determine where each component is coming from (including the raw material used to create each component), and hypothesize why the specific material was chosen for the design. As part of this activity, students can be asked to think about where they believe the components end up (i.e., recycle or landfill) after being discarded from a person's home. Lastly, students can be asked to design solutions for recycling each component, thus shifting their understanding of design from simply based on physical products to processes. This activity would draw from students' tinkering knowledge from home and provide a structured learning approach that helps them think critically about how and why the appliance/device was designed in a certain way and the impact the design solution has on the environment. This activity can be expanded to high school students to meet the Earth and Human Activity performance expectations HS-ESS3-2 ("evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios") and HS-ESS3-4 ("evaluate or refine a technological solution that reduces impacts of human activities on natural systems"; NGSS Lead States, 2013, p. 125). High school students can be asked to take apart an appliance/device, identify the material used, and conduct an investigation on the raw material to understand where it comes from; the social, economic, and environmental costs of obtaining it from the manufacturer; if and how it is recycled; and what impact extracting, using, and recycling the material has on the environment at local and global scales. Lastly, students can be asked to identify and assess the strengths and limitations of eco-friendly replacements to some of the components in their chosen appliance/device and then redesign the appliance/device using eco-friendly material.

Engineering Design Process

The NGSS engineering design standards require that students become capable of defining a problem, developing possible solutions, and improving designs. In this practical strategy section, we underscore the processes involved in the design solution and call attention to the areas where students' funds of knowledge could be leveraged. In the middle school and high school grade-bands, students are expected to demonstrate an understanding of how to define the criteria and constraints of a design problem (MS-ETS1-1 and HS-ETS1-1) and evaluate solutions to determine how well they meet the specified criteria and constraints (MS-ETS1-2 and HS-ETS1-3; NGSS Lead States, 2013). A clear distinction between the engineering design expectations from middle school to high school is an emphasis on real-world challenges in the high school grade-bands. In the early phases of design, students start to understand that engineering design problems are ill-defined (Watkins et al., 2014), thus requiring students to consider the perspectives of clients, end-users, and other affected stakeholders as well as the impact associated with the design. Identifying the criteria and constraints of a problem can be achieved through students' funds of knowledge of perspective taking and mediational skills. Students' ability to examine a situation and put themselves in another person's shoes (i.e., perspective taking) should be emphasized as a practice of identifying the criteria and constraints of a problem and evaluating the effectiveness of the proposed solutions for various stakeholders. Students at the high school level can be invited to interview potential end-users in their neighborhood or community to understand their perspectives on the problem, thus capitalizing on their perspective-taking capabilities. Likewise, high school students can pitch their design solutions to potential end-users and serve as mediators between how a solution was intended to support the community and the perception or reaction the community members have on the proposed solution.

Lastly, an important practice of engineers is their ability to work effectively in teams. Moore et al.'s (2014) framework for engineering education acknowledges teamwork as a key indicator that students should know throughout K-12 education. Recognizing the importance of teamwork as an essential practice of an engineer and providing students with an opportunity to practice working in teams can bridge their funds of knowledge of perspective taking and mediational skills to engineering literacy. Engineering-literate students should be engaged in the engineering design process, engineering habits of mind, and the role engineering plays in society and "its application to personal, social, and cultural situations" (National Academies of Sciences Engineering and Medicine, 2020). We encourage educators to consider students' funds of knowledge that are more than the abilities to tinker; interpersonal skills are equally important and valuable assets of an engineer's practice.

Conclusion

Our study builds upon a long line of research arguing that interest and self-efficacy beliefs are important contributing factors towards students' decisions to pursue a STEM degree by investigating how students' funds of knowledge from home foster these affective factors. Three funds of knowledge constructs (i.e., tinkering knowledge from home, perspective taking, and mediational skills) were found to contribute to minoritized students' sustained interest in engineering and to support their self-efficacy beliefs. These findings underscore the importance of interpersonal knowledge and skills for developing interest and self-efficacy in engineering. Crucially, we found that when minoritized students could explicitly recognize connections between their accumulated bodies of knowledge and engineering—and leverage those connections—it supported their certainty of majoring in engineering. Thus, we offered strategies to help educators encourage students to use their funds of knowledge in their STEM courses.

However, our study also cautions that minoritized students do not readily identify the importance or utility of their specific home knowledge and its engineering application. We found that engineering self-efficacy did not have a significant intermediating relationship between students' funds of knowledge and certainty of choosing engineering. This means that in order for these efforts of leveraging students' funds of knowledge to be successful, it is essential to shift the conversation around the types of engineering activities that are viewed as legitimate forms of participation. Day-to-day experiences at home should be celebrated as sources of knowledge. Our study confirmed that students' home practices of building things, fixing things, working on machines, and assembling or disabling household items cultivated their desire to learn more about engineering and solidified their major choice. Yet often students narrowly believe that legitimate engineering-related hands-on pre-college activities are those involving LEGOs, K'Nex, or robotics, and accounts of students' triggered interest in engineering often focus on these activities (Cruz & Kellam, 2018; Verdín, Smith, & Lucena, 2019; Wendell & Rogers, 2013). This view of legitimate participation and preparation is so pervasive that one student, in an interview, said, "I haven't had any engineering experiences, ever…I didn't even play with Legos or anything" (Verdín, Smith, & Lucena, 2019). Moreover, studies have found that minoritized students are less likely than other groups to participate in out-of-school or extracurricular activities (Heath et al., 2018; Meier et al., 2018; Yu et al., 2015) and these forms of participation benefit students' decision to pursue an engineering major (Dabney et al., 2012; Godwin, Sonnert et al., 2016; Verdín, Godwin, Sonnert et al., 2018). Thus, engineering learning experiences should not be limited to activities that are not equitably available to all.

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Appendix A

Model 1. Standardized OLS regression coefficients with confidence intervals (standard errors in parentheses) estimating engineering interest, self-efficacy, and certainty of majoring in engineering. Tinkering knowledge from home.

	Engineering interest (M_1)			Engineering self-efficacy (M_2)			Certainty of majoring in engineering (Y)		
	Coeff.	***p***	**95% CI**	**Coeff.**	***p***	**95% CI**	**Coeff.**	***p***	**95% CI**
Parents with bachelor's degree or higher (coded = 1)	0.02 (0.21)	0.886	−0.38, 0.44	0.13 (0.21)	0.146	−0.11, 0.73	−0.17 (0.22)	0.046	−0.86, −0.01
Gender (male = 1)	−0.02 (0.18)	0.837	−0.39, 0.32	0.15 (0.23)	0.056	−0.01, 0.73	−0.11 (0.19)	0.136	−0.66, 0.09
Not a Pell recipient (coded = 1)	−0.09 (0.19)	0.386	−0.55, 0.22	−0.08 (0.20)	0.363	−0.58, 0.21	0.11 (0.20)	0.191	−0.14, 0.67
Majority group (coded = 1)	−0.07 (0.19)	0.489	−0.52, 0.25	0.04 (0.20)	0.587	−0.28, 0.50	0.06 (0.20)	0.556	−0.28, 0.51
Tinkering knowledge: home (X)	0.40 (0.06)	0.000	0.14, 0.38	0.003 (0.07)	0.968	−0.13, 0.14	0.08 (0.07)	0.344	−0.07, 0.20
Engineering interest (M_1)				0.65 (0.10)	0.000	0.62, 1.01	0.36 (0.13)	0.000	0.23, 0.73
Engineering self-efficacy (M_2)							0.38 (0.10)	0.000	0.21, 0.59
	$R^2 = 0.18$			$R^2 = 0.46$			$R^2 = 0.50$		
	$F(5, 109) = 4.86, p < 0.001$			$F(8, 108) = 15.50, p < 0.000$			$F(7, 107) = 15.09, p < 0.000$		

Model 2. Standardized OLS regression coefficients with confidence intervals (standard errors in parentheses) estimating engineering interest, self-efficacy, and certainty of majoring in engineering. Perspective taking.

	Engineering interest (M_1)			Engineering self-efficacy (M_2)			Certainty of majoring in engineering (Y)		
	Coeff.	***p***	**95% CI**	**Coeff.**	***p***	**95% CI**	**Coeff.**	***p***	**95% CI**
Parents with bachelor's degree or higher (coded = 1)	0.02 (0.11)	0.881	−0.44, 0.38	0.13 (0.21)	0.144	−0.11, 0.73	−0.17 (0.22)	0.038	−0.88, −0.03
Gender (male = 1)	−0.06 (0.18)	0.502	−0.23, 0.50	0.15 (0.18)	0.049	0.00, 0.71	−0.10 (0.19)	0.188	−0.61, 0.12
Not a Pell recipient (coded = 1)	−0.16 (0.20)	0.121	−0.70, 0.08	−0.08 (0.20)	0.357	−0.59, 0.21	0.10 (0.21)	0.238	−0.16, 0.65
Majority group (coded = 1)	−0.00 (0.20)	0.967	−0.40, 0.38	0.04 (0.20)	0.578	−0.28, 0.50	0.05 (0.20)	0.487	−0.26, 0.54
Perspective taking (X)	0.34 (0.11)	0.000	0.20, 0.63	0.01 (0.12)	0.904	−0.22, 0.24	0.04 (0.12)	0.601	−0.17, 0.30
Engineering interest (M_1)				0.65 (0.10)	0.000	0.62, 1.01	0.38 (0.13)	0.000	0.25, 0.75
Engineering self-efficacy (M_2)							0.38 (0.10)	0.000	0.20, 0.59
	$R^2 = 0.16$			$R^2 = 0.46$			$R^2 = 0.49$		
	$F(5, 109) = 4.05, p < 0.002$			$F(6, 108) = 15.51, p < 0.000$			$F(7, 107) = 14.92, p < 0.000$		

Model 3. Standardized OLS regression coefficients with confidence intervals (standard errors in parentheses) estimating engineering interest, self-efficacy, and certainty of majoring in engineering. Mediational skills.

	Engineering interest (M_1)			Engineering self-efficacy (M_2)			Certainty of majoring in engineering (Y)		
	Coeff.	***p***	**95% CI**	**Coeff.**	***p***	**95% CI**	**Coeff.**	***p***	**95% CI**
Parents with bachelor's degree or higher (coded = 1)	−0.03 (0.21)	0.815	−0.48, 0.38	0.13 (0.21)	0.144	−0.11, 0.73	−0.18 (0.22)	0.038	−0.89, −0.03
Gender (male = 1)	0.08 (0.18)	0.385	−0.21, 0.53	0.15 (0.18)	0.049	0.00, 0.71	−0.10 (0.19)	0.183	−0.62, 0.12
Not a Pell recipient (coded = 1)	−0.13 (0.20)	0.242	−0.65, 0.17	−0.08 (0.20)	0.357	−0.58, 0.21	0.10 (0.21)	0.198	−0.14, 0.67
Majority group (coded = 1)	−0.07 (0.21)	0.509	−0.54, 0.27	0.04 (0.20)	0.578	−0.29, 0.50	0.05 (0.20)	0.497	−0.26, 0.53
Mediational skills (X)	0.19 (0.08)	0.045	0.00, 0.31	0.01 (0.08)	0.852	−0.14, 0.17	−0.05 (0.08)	0.456	−0.21, 0.10
Engineering interest (M_1)				0.65 (0.10)	0.000	0.63, 1.00	0.40 (0.12)	0.000	0.28, 0.77
Engineering self-efficacy (M_2)							0.38 (0.10)	0.000	0.21, 0.59
	$R^2 = 0.09$			$R^2 = 0.46$			$R^2 = 0.50$		
	$F(5, 109) = 1.84, p < 0.110$			$F(6, 108) = 15.51, p < 0.000$			$F(7, 107) = 15.00, p < 0.000$		

Standardized OLS regression coefficients with confidence intervals (standard errors in parentheses) estimating engineering interest, self-efficacy, and certainty of majoring in engineering. I see connections between experiences at home and what I am learning in my engineering courses.

	Engineering interest (M_1)			Engineering self-efficacy (M_2)			Certainty of majoring in engineering (Y)		
	Coeff.	***p***	**95% CI**	**Coeff.**	***p***	**95% CI**	**Coeff.**	***p***	**95% CI**
Parents with bachelor's degree or higher (coded = 1)	−0.04 (0.22)	0.697	−0.52, 0.35	0.12 (0.21)	0.171	−0.13, 0.69	−0.18 (0.22)	0.037	−0.89, −0.03
Gender (male = 1)	0.04 (0.19)	0.655	−0.29, 0.46	0.12 (0.18)	0.107	−0.06, 0.65	−0.10 (0.19)	0.197	−0.62, 0.13
Not a Pell recipient (coded = 1)	−0.11 (0.21)	0.289	−0.62, 0.19	−0.07 (0.20)	0.382	−0.56, 0.21	0.10 (0.20)	0.207	−0.15, 0.66
Majority group (coded = 1)	−0.10 (0.21)	0.255	−0.61, 0.19	0.01 (0.20)	0.914	−0.37, 0.41	0.05 (0.21)	0.538	−0.28, 0.53
See connections (X)	0.18 (0.06)	0.062	−0.01, 0.22	0.15 (0.06)	0.048	0.00, 0.22	0.00 (0.06)	0.992	−0.12, 0.12
Engineering interest (M_1)				0.62 (0.10)	0.000	0.61, 0.97	0.39 (0.12)	0.000	0.27, 0.76
Engineering self-efficacy (M_2)							0.38 (0.10)	0.000	0.20, 0.60
	$R^2 = 0.07$			$R^2 = 0.48$			$R^2 = 0.49$		
	$F(5, 109) = 1.73$, $p < 0.135$			$F(6, 108) = 16.75$, $p < 0.000$			$F(7, 107) = 14.84$, $p < 0.000$		

Standardized OLS regression coefficients with confidence intervals (standard errors in parentheses) estimating engineering interest, self-efficacy, and certainty of majoring in engineering. I draw on my previous experiences at home when little instruction is given on how to solve an engineering task.

	Engineering interest (M_1)			Engineering self-efficacy (M_2)			Certainty of majoring in engineering (Y)		
	Coeff.	***p***	**95% CI**	**Coeff.**	***p***	**95% CI**	**Coeff.**	***p***	**95% CI**
Parents with bachelor's degree or higher (coded = 1)	−0.03 (0.21)	0.793	−0.48, 0.37	0.13 (0.21)	0.133	−0.10, 0.72	−0.18 (0.22)	0.038	−0.88, −0.03
Gender (male = 1)	0.08 (0.18)	0.653	−0.29, 0.45	0.13 (0.18)	0.092	0.05, 0.66	−0.10 (0.19)	0.175	−0.63, 0.12
Not a Pell recipient (coded = 1)	−0.13 (0.20)	0.172	−0.69, 0.12	−0.10 (0.20)	0.244	−0.62, 0.16	0.10 (0.20)	0.239	−0.16, 0.65
Majority group (coded = 1)	−0.07 (0.21)	0.403	−0.57, 0.23	0.02 (0.19)	0.789	−0.33, 0.44	0.05 (0.20)	0.577	−0.26, 0.53
Draw on previous experiences (X)	0.21 (0.06)	0.024	0.2, 0.25	0.15 (0.06)	0.044	0.00, 0.23	0.05 (0.06)	0.592	−0.09, 0.15
Engineering interest (M_1)				0.62 (0.09)	0.000	0.60, 0.96	0.40 (0.12)	0.000	0.27, 0.75
Engineering self-efficacy (M_2)							0.37 (0.10)	0.000	0.19, 0.59
	$R^2 = 0.09$			$R^2 = 0.48$			$R^2 = 0.49$		
	$F(5, 109) = 2.08$, $p < 0.074$			$F(6, 108) = 16.80$, $p < 0.000$			$F(7, 107) = 14.92$, $p < 0.000$		