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Surveying the Cultural Assets of Engineering Students: An Exploratory Quantitative Study

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Surveying the Cultural Assets of Engineering Students: An Exploratory Quantitative Study

Abstract

The cultural assets that engineering learners use to meet coursework demands and navigate engineering programs can be invisible to engineering educators. To examine these cultural assets of engineering learners, a quantitative instrument was designed using Community Cultural Wealth (CCW) as a theoretical lens. It was distributed as part of a tri-campus study. CCW theory delineates six forms of cultural capital that reflect the assets and resources people accumulate through their ways of living. These forms include aspirational, linguistic, familial, social, navigational, and resistant capitals. An 18-item survey was designed to connect engineering students' cultural assets to the ways they navigate their present-day lives as college students and foresee their future lives as engineers. The study recruited a sample of undergraduate students registered in engineering majors at three institutions of higher education including a public Hispanic Serving Institution (Angelo State University), a Tier-2 research institution (James Madison University), and a Tier-1 research institution (University of Colorado Boulder). The survey findings corroborate results found in other studies. Although our study is limited by a sample size of just seventy-five students from three different engineering schools, the findings show two key results that we present in this paper. First, Students of Color scored higher than White Students on a combined index of survey items measuring the six forms of cultural capital. Second, we discuss how Students of Color, who are more likely to be First-Generation students, use their cultural assets in unique ways. We discuss the important implications of these findings for developing and implementing engineering instructional practices and curricula.

Introduction

The National Science Foundation's (NSF's) biennial report on the representation of women, minorities, and persons with disabilities in science, technology, engineering, and mathematics (STEM) education and employment highlights the continuing progress made in diversifying the engineering workforce [NSF, 2023]. These findings fuel the potential for new innovations by leveraging individuals' different backgrounds, experiences, and points of view [NSF, 2023]. In response to a call from engineering education leaders [Leydens & Lucena, 2017; Baillie & Pawley, 2012; Riley, 2008], peers have adopted asset-based instructional strategies and make continuing strides to transform engineering education in the 21st Century [Budinoff & Subbian, 2021; Gravel *et al*., 2021; Mejia *et al*., 2019]. As engineering educators continue to modernize instructional practices and engineering curricula across the nation, we find ourselves encountering and challenging deep-seated systemic inequities entrenched in engineering curricula and in our own instructional practices. Yet, we find ourselves discovering new ways to upend those deficit-based modes of instruction, and we are continually striving to meet the needs of our engineering learners in our classrooms and curricula.

The cultural foundations which engineering curricula, engineering colleges, and engineering workplaces all share can trace their roots to the early 20th Century. Frehill (2004) conducted archival research and found that engineering was couched as a masculine space to "prove manhood," ultimately creating unwelcoming or hostile environments for People of Color and

White women through the present [Miller *et al*., 2023]. As a long-lasting consequence, typical engineering curricula in the 21st Century are entrenched with hidden elements [Polmear *et al.*, 2019; Villanueva, 2018] that discourage the participation of marginalized people. Engineering collegiate cultures can also become value-neutral, where an over-emphasis on 'rigor' [Riley, 2017] can disproportionately impact marginalized people in engineering spaces and promote deficit-based instructional practices. These formative pieces lay the foundation for engineering professional spaces to perpetuate, to this day, sexist [Dietz *et al*., 2021; Smith & Gayles, 2018; Powell & Sang, 2015; Faulkner, 2009], racist [Long, 2021; Douglas *et al.*, 2020], and homophobic [Denissen & Saguy, 2014] workplace cultures.

Nevertheless, people from marginalized groups have navigated and found success in this hostile engineering landscape, by drawing upon their cultural assets to overcome systemic barriers [Samuelson & Litzler, 2016]. Engineering educators are increasingly aware of these assets and are developing new, asset-based instructional approaches that recognize non-canonical skills and knowledge that students bring with them into the engineering classroom [Olayemi & DeBoer, 2021; Jordan *et al*., 2019; Mobley & Brawner, 2019; Castaneda & Mejia, 2018], translating into increased retention of First-Generation students and Students of Color in the engineering classroom [Gonzalez & Wilson, 2020; Winkle-Wagner *et al*., 2020; Svihla *et al*., 2017] and into broadened representation in the engineering workforce [Chubin *et al*., 2005]. These positive outcomes are underpinned by the notion that all engineering learners maintain vast knowledge, experiences, and skills that can be used to meet the demands of engineering coursework and engineering programs. Yet, those cultural assets may remain invisible, unrecognized, and under-leveraged by engineering educators. As engineering educators continue to make strides in supporting their diverse learners, additional steps are needed to make visible the unseen cultural assets that engineering learners use in the engineering classroom as they develop into the engineers of the 21st-century STEM workforce.

This paper presents the findings of an exploratory, quantitative study of the cultural assets that engineering students use while enrolled in undergraduate engineering degree programs. Specifically, we developed and distributed an instrument at three institutions of higher education in the United States (US): a public, Hispanic Serving Institution (Angelo State University); a Tier-2 research institution (James Madison University); and a Tier-1 research institution (University of Colorado Boulder). This paper summarizes the development of the quantitative instrument using the theory of Community Cultural Wealth (CCW), the statistical treatment of the survey results, and a discussion of the implications and limitations of some key survey findings. We do so to answer our central research question: "What cultural assets do undergraduate engineering students use in their development as engineers?"

Background

Yosso's (2005) seminal paper on Community Cultural Wealth (CCW) – which has been cited in nearly 10,000 instances across wide-ranging research studies – stems from Critical Race Theory (CRT). CRT is a theory first used in Critical Legal Studies to understand the systemic inequities in the legal system and to recognize more broadly the lived experiences of people, particularly People of Color, engaged in the study of law [Delgado, 2023]. CCW brings to light the cultural assets that People of Color maintain, and those cultural assets are enumerated across six forms of cultural capital [Yosso, 2005]:

- **Aspirational Capital (AC)** refers to the abilities that emerge from a person's experience to work towards and achieve personal dreams or aspirations.
- **Linguistic Capital (LC)**, on the other hand, refers to skills gained, especially by multilingual individuals, from their diverse modes of communication with others that can be adapted based on different situations.
- **Familial Capital (FC)** is the sense of support rooted in community morals, values, and norms that are passed to individuals through familial experience.
- **Social Capital (SC)**, by contrast, refers to a person's ability to apply and utilize skills and knowledge learned through experiences with other members of the broader community.
- **Navigational Capital (NC)** consists of a person's ability to interact with the bureaucratic organizations and social institutions of the community, professions, and/or society; and to leverage those organizations' and institutions' resources.
- **Resistant Capital (RC)** represents skills learned by individuals from experiences rooted in racial, ethnic, social class, religion, disabilities, or other systemic social inequalities in the community and/or society.

CCW has been increasingly used as a qualitative theoretical lens in engineering education and STEM education research to explore the ways in which marginalized people have navigated engineering and STEM cultures [Dika, 2018; Martin, 2016; Samuelson & Litzler, 2016]. In one study, CCW was used to understand how marginalized students and faculty experienced microaggressions [Acevedo & Solorzano, 2021]. In another study, researchers explored how undergraduate Black men in engineering drew on familial capital to navigate unwelcoming engineering environments [Smith, 2022]. Mexican-American and Latinx learners, in other studies, regularly drew on their strengths in cultivating *familismo* and other cultural assets in their progression through engineering programs [Rodriguez *et al*., 2023; Rincón & Rodriguez, 2021; Wilson-Lopez *et al*., 2016]. While many of these studies employ qualitative and mixed methods, several have used quantitative methods [Denton *et al*., 2020]. In a systematic review of CCW in STEM education research, Denton *et al*. (2020) identified two studies that utilize a solely quantitative approach. The first quantitative study explored the relationship between the capitals of CCW and the self-efficacy of engineering students through a 51-question survey [Dika, 2015]. In that study, only nine of those 51 questions focused on the CCW capitals, specifically aspirational and navigational capitals. The second quantitative study examined first-year students majoring in various science and math subjects by asking if specific events or factors (such as their favorite high school teacher or attendance to a university-funded summer camp) made them more or less interested in attending college [Kester, 2017]. The results of this questionnaire allowed for an interpretation of the social capital possessed by the students interviewed. Neither of the two quantitative studies explored all six capitals of CCW. In fact, only three of the six capitals were explored and both studies correlated CCW to another construct rather than concentrating on CCW alone. Yet, many studies regarding CCW have centered their attention on marginalized groups in engineering such as First-Generation students and Students of Color.

According to the National Association of Student Personnel Administrators (NASPA), First-Generation college students are those whose "parents did not complete a 4-year college or university degree" [NASPA, (n.d.)]. Although there has been a steady decline in the percentage of First-Generation students in college over the last few decades, over a third of all students seeking their bachelor's degrees still are considered First-Generation college students. Therefore, they often experience the impacts associated with this designation such as impeded access to post-secondary institutions, poor retention, and graduation rates through their degree program, and low self-efficacy [Startz, 2022; Cataldi *et al,* 2018; Chen and Carroll, 2005; Hernandez, 2018].

Often, the term Students of Color refers to students who come from a non-White or non-European ethnic background, and students who self-report as a Student of Color generally identify as Asian American/Pacific Islanders, African American, Hispanic/Latino, and Native American/American Indian [IGI Global, (n.d.)]. Self-reporting demographics acknowledge the dynamic nature of race and ethnicity that is developed not only through biological means but also various socialization methods and allows for the inclusion of students who identify as multiracial [Parker *et al.*, 2022; Flanagin *et al*., 2021]. In higher education settings, it has been documented that Students of Color must overcome barriers to success, including lack of available mentors, stereotyping, and feelings of isolation, all of which contribute to low retention rates [Banks & Dohy, 2018; Harris & Linder, 2018; Griffin *et al*., 2010].

These two demographic groups' cultural assets are being increasingly explored by engineering and STEM education researchers, and CCW has been used as a theoretical lens to understand those cultural assets using quantitative, qualitative, and mixed methods [Hiramori *et al.*, 2021; Denton *et al*., 2020; Dika *et al*., 2018; Samuelson *et al.*, 2016]. While there are limitations to using quantitative scales to measure the assets of Students of Color [Sablan, 2019], the use of quantitative outcomes can drive education policy and research [Covarrubias & Veliz, 2013] and can in fact be measured using intelligently designed instruments [Sablan, 2019]. We focus our attention on First-Generation students and Students of Color since previous studies in engineering education research have explored those particular demographic groups in supporting the broadening of participation in engineering education and the engineering workforce.

Methodology

In this study, we opted to develop a quantitative instrument that sought to measure all six forms of capital that undergraduate students from all demographic populations enrolled in an engineering degree program might hold across three distinct institutional contexts: 1) a public, Hispanic Serving Institution in the US Southwest (Angelo State University); 2) a Tier-2 research institution in the US Mid-Atlantic (James Madison University); and 3) a Tier-1 research institution in the Mountain West (University of Colorado Boulder). An 18-item, 5-point Likert scale survey was developed, whereby three items were associated with the six dimensions of CCW. Within each dimension, an item was developed to indicate a respondent's "having or holding" of that specific CCW dimension. A second item was developed to indicate a respondent's "development" toward that specific CCW dimension. Those items were categorized as "Positive" and "Positive-Developing," respectively. A third item was developed to indicate a respondent's "not having or not holding" a specific CCW dimension. Those items were categorized as "Negative." As such, the three items within a specific CCW dimension were devised to lead toward internal consistency of the instrument, whereby a respondent positively responding to "having or holding" a specific CCW would be anticipated to answer negatively to "not having or not holding" that same specific CCW dimension.

An initial survey was developed by Castaneda and was subjected to four rounds of revisions before distribution at the three institutions. Each item was constructed as analogous statements that engineering students might encounter in their formation as engineers at any institution within the United States. Castaneda developed the initial instrument, and the instrument was revised in the second and third rounds by Bolhari and Stewart. Those revisions entailed deconvoluting the language in all items from representing or conflating more than one specific CCW dimension in that item. A final, fourth round of revision was realized based on a trial distribution of the instrument to four undergraduate research students who identified instances of unclear or interpretative language. The final, 18-item instrument is shown in Figure 1. An additional 19 questions were used to collect demographic information and engineering degree-related information across the three specific institutions where the survey was distributed.

The Likert-scale responses were converted to the equivalent numerical scale shown in Table 1. In order to account for the fact that Negative items indicated an absence of a particular CCW dimension, they were assigned negative values.

Once converted, the three items within a CCW dimension were summed together. For example, if a respondent answered Strongly Agree (+2), Somewhat Agree (+1), and Somewhat Disagree (+1) for the Positive, Positive-Developing, and Negative items, respectively, then the score within that CCW dimension for that respondent would be 4 (2+1+1). All 75 respondents' scores were averaged, and comparisons between different demographic groups could be made.

Statistical Analysis

We explored a variety of variance tests and demographic groupings to discern statistically significant correlations within our data set. A variance test is a statistical tool used to compare two groups and to determine whether there is a statistical difference between them, allowing the quantification of the difference between the groups [Fernandez, 2020]. By running a variance test, p-values (or probability values) can be obtained. A p-value is a probability of obtaining test results at least as extreme as the results actually observed during the test.

Four statistical treatments were considered in this study: (1) the Chi-Square Test and Fisher's Exact Test, (2) Welch's t-Test, (3) Levene's Test, and (4) the Brown-Forsythe Test. Each statistical test provides for an evaluation of whether there is sufficient evidence in comparing two populations to reject the null hypothesis, commonly interpreted to mean that the two populations are not the same.

The Chi-Square Test is a common test for checking if observed frequencies in one or more categories match the expected frequencies. This test can be used with one or multiple variables. The multivariable test is the Chi-Square Test of Independence, which determines if two categorical variables are related in any way [Starne & Tabor, 2018]. Once the Chi-Square value is found, it must be compared to a critical value in a reference table, which relates the degrees of freedom and the significance level to determine the critical value. Due to the non-exactness of the Chi-Square Test for smaller samples, a Fisher's Exact Test can be used. A Fisher's Exact Test is used with two nominal variables to find out if the proportions from one variable are different among values of the other [Bind & Rubin, 2020]. Due to the test's exact nature, it is more accurate than a Chi-Square Test alone.

Your answers to the following questions will help us understand your approach to engineering as a career field. Please use the 5-point scale to indicate your level of agreement with each statement.

Agree – Somewhat Agree – Neither Agree nor Disagree – Somewhat Disagree – Disagree

A. My engineering classes are very easy for me, and I am motivated to reach my goal of becoming an engineer someday.
B. I am able to speak or write about engineering in more than one language.
C. When I talk to family relatives about engineering, they are able to relate to me and tell me stories about other engineers or professionals in my family tree.
D. I have a group of older working professional friends who always offer me advice about challenges in my engineering coursework and opportunities for professional development when needed.
E. I know who to call or email when I have questions about my engineering major or engineering employment opportunities.
F. I believe engineers should advocate for political change related to poverty, inequality, or a similar issue.

G. Even though I struggle to earn the best grades in my engineering classes, I am motivated to reach my goal of becoming an engineer someday.
H. It is important for me to learn how to speak or write in more than one language for my future as an engineer.
I. Elder members in my family don't understand engineering, but I am able to talk and share stories with younger family members who are also pursuing college degrees.
J. A group of friends and I help each other make sense of challenges in my engineering coursework and opportunities for professional development, even though none of us are experts.
K. I believe it is important to attend info-sessions and club meetings to network with people who can help me understand my engineering major and engineering employment opportunities.
L. I am part of an organization that is helping me see how much poverty and inequality there is in the world.

M. There are many challenges in my life, and I am losing motivation of becoming an engineer someday.
N. It is not necessary to speak or write in more than one language for me to become an engineer.
O. None of my family members really understand engineering and do not understand my goals for becoming an engineer.
P. I feel like I am on my own when it comes to understanding challenges in my engineering coursework and opportunities for professional development.
Q. It is not important to get to know people at info-sessions and club meetings because my resume is all I need for an engineering employment opportunity.
R. I believe responding to community problems is the responsibility of political and civic leaders, not of engineers.

Figure 1. Items A, G, and M relate to *aspirational capital*. Items B, H, and N relate to *linguistic capital*. Items C, I, and O relate to *familial capital*. Items D, J, and P relate to *social capital*. Items E, K, and Q relate to *navigational capital*. Items F, L, and R relate to *resistance capital*. Additionally, Items A, B, C, D, E, and F relate to *having* or *holding* a CCW capital dimension. Items G, H, I, J, K, and L relate to a *developing* CCW capital dimension. Items M, N, O, P, Q, and R relate to *not having* a CCW capital dimension.

Table 1. Likert scale numerical conversation for Positive, Positive-Developing, and Negative items.

	Positive	Positive-Developing	Negative
Strongly Agree	2	2	-2
Somewhat Agree	1	1	-1
Neutral	0	0	0
Somewhat Disagree	-1	-1	1
Strongly Disagree	-2	-2	2

Welch's t-Test approaches the comparison of two groups based on the assumption that the two groups have unequal variances (i.e., unequal variance is the null hypothesis of the test), while Levene's Test assumes equal variances as the null hypothesis. This distinction between Welch's and Levene's t-Tests results in slightly different p-values. Levene's Test uses deviations from group means, which can result in highly-skewed data that violates the assumption of normality. The Brown-Forsythe Test attempts to correct this skewness by using deviations from group medians. The Brown-Forsythe Test, as a consequence, is a more robust statistical test because it is less likely than Levene's Test to incorrectly declare that the assumption of equal variances has been violated. We recognize that there is no agreement in statistics on which statistical treatment is the better approach to use. Some experts argue that Welch's t-Test leads to better decisions regarding the rejection of the null hypothesis. In our paper, we found that the use of any statistical treatment led to a common rejection of the null hypothesis (i.e., significant p-values) in all instances of our comparisons. As such, we report values of the Brown-Forsythe Test for its robustness.

The generated survey data was analyzed using RStudio statistical software and verified in select instances by hand calculation. Our study used the Brown-Forsythe Test to compare eleven different demographic categories and discern whether there was a correlation between the demographic category and a specific CCW dimension.

From a variance test, Point Biserial Correlation (PBC) can be run. This is a special case of Pearson's correlation coefficient. PBC is the measure of the relationship between two variables; one continuous variable and one naturally binary variable [Stephanie, 2016]. The value obtained from the test ranges from zero to one with zero representing no relationship and one being a perfect relationship [Stephanie, 2016]. When using this test, caution must be taken as forcing data to become binary can make the results of the test less reliable. PBC requires binary variables, and we accommodate this by collapsing each demographic category into binary variables. For example, the racial category was split across respondents who self-reported being White and all those who reported another racial or ethnic identity. The PBC values were deemed to be moderately correlated if above 0.20 and strongly correlated if above 0.50, which are typical thresholds in social science-based quantitative studies [Varma, (n.d.)]. When the PBC value is positive, then the correlation between the two variables tends toward the second variable. When the PBC value is negative, then the correlation between the two variables tends toward the first variable.

Results

The survey instrument was distributed in March 2022 at three institutions in compliance with University of Colorado Boulder's Institutional Review Board (IRB) protocol # 20-0400. A total of 1,110 undergraduate engineering students, enrolled in a department or college of engineering, received an invitation to participate in the survey. A total of 100 responses were received over a 3-week time period, representing a 9% survey response rate. Respondents who did not complete the survey were removed from the subsequent analysis. As a result, the sample size of our survey was reduced to 75 respondents. The demographic breakdown of the respondents is shown in Table 2. The agglomerated item results are shown in Table 3.

Table 2. Demographic breakdown of the three institutions, whereby Angelo State University (ASU) is a public, Hispanic Serving Institution in the US Southwest; James Madison University (JMU) is a Tier-2 research institution in the US Mid-Atlantic; and University of Colorado Boulder (UCB) is a Tier-1 research institution in the Mountain West. Two respondents did not specify gender nor racial/ethnic identity, so they were removed from certain variance tests.

Demographic	ASU	JMU	UCB	Total	
Male	15	5	21	41	73
Female	7	3	22	32	
First-Generation	11	2	11	24	75
non-First-Generation	13	6	32	51	
White Students*	9	8	30	47	73
SOC**	13	0	13	26	

*Surmised from a question asking if White.
**Surmised from a question asking whether the respondent identified as Hispanic, Latinx, Chicanx; Asian; Black or African American; Middle Eastern; Arab American; or More than One Ethnicity.

A Chi-Square Test with Fisher's Exact value was used to measure the association between Students of Color and First-Generation students (see Table 4). The result shows that First-Generation students comprised 22 or 30.14% of the sample. Half (50.00%) of the Students of Color who were surveyed were First-Generation students along with 9 or 19.15% of White Students. A Fisher's Exact value of 0.0083 rejects the null hypothesis that White Students and Students of Color are equally likely to be First-Generation students. Thus, in our survey sample, Students of Color are significantly more likely to be First-Generation students. We categorized our respondents into a comparison between First-Generation students and non-First-Generation students (see Table 5), and observed statistical significance across six items (B, C, D, H, O, and P) representing three unique CCW dimensions (Aspirational, Linguistic, and Navigational).

Items B and H in Table 5 represent the "Positive" and "Positive-Developing" elements of the Linguistic Capital dimension. Item B prompted respondents about their ability to speak or write about engineering in more than one language while Item H prompted respondents about the importance of learning to speak or write in more than one language in relation to their future as engineers. Item B scored p = 0.0297 value between the two groups, and the PBC value of -0.251 suggests a moderately strong result that First-Generation students are more inclined to speak or write about engineering in more than one language than non-First-Generation students. Similarly, Item H scored p = 0.0001, and the PBC value of -0.436 suggests that First-Generation students valued the ability to speak or write in more than one language in their futures as engineers more importantly than non-First-Generation students. Items C and O in Table 5 represent "Positive" and "Negative" elements of the Familial Capital dimension. Item C prompted respondents about their family's ability to relate to them and tell them about other engineers or professionals in their family, while Item O prompted respondents in having no family members who understand engineering or their goals to become an engineer.

Table 3. Agglomerated results of the 18-item questionnaire across the 75 survey responses. The mean score for items M, N, O, P, Q, and R have been negated in accordance with our Likert scale numerical conversion (see Table 1) and are shown in the table with *italicized* font.

Dimension	**Item**	**Statistical Analysis**			
		Mean		Standard Deviation	
Aspirational Capital	A	1.347	0.764	0.813	1.293
	G	1.240		1.037	
	*M**	*-0.293*		1.271	
Linguistic Capital	B	-0.813	-0.133	1.548	1.512
	H	0.053		1.432	
	*N**	*0.36*		1.311	
Familial Capital	C	-0.347	-0.400	1.601	1.449
	I	-0.187		1.43	
	*O**	*-0.667*		1.266	
Social Capital	D	-0.333	0.244	1.464	1.484
	J	0.947		1.24	
	*P**	*0.120*		1.461	
Navigational Capital	E	0.947	0.280	1.324	1.534
	K	1.053		1.025	
	*Q**	*-1.16*		1.079	
Resistant Capital	F	1.03	-0.187	1.325	1.524
	L	-0.987		1.191	
	*R**	*-0.6*		1.241	

Table 4. Cross-tabulation table of 73 survey responses, whereby two responses from the sample size of 75 were excluded for not indicating a racial/ethnic identity.

	White Students	Students of Color	Total
First-Generation	19.15% (*n* = 9)	50.00% (*n* = 13)	30.14% (*n* = 22)
non-First-Generation	80.85% (*n* = 38)	50.00% (*n* = 13)	69.86% (*n* = 51)
Total (*n*)	47	26	73
Total (%)	100.00%	100.00%	100.00%
Chi-Square Test	**Value**	**DF**	**p=**
Fisher's Exact Value	7.567	1	0.0083

Table 5. Item analysis between First-Generation Students (*n* = 24) and non-First-Generation Students (*n* = 51). *Italicized* items and means have been negated; and ***italicized, bolded*** font indicates a result with statistical significance.

Dimension	Item	First-Generation		non-First-Generation		Statistical Test		
		Mean	Std. Deviation	Mean	Std. Deviation	t-value	p-value	PBC
Aspirational Capital	A	1.167	1.090	1.431	0.410	1.321	0.191	0.153
	G	1.458	0.833	1.137	1.114	-1.255	0.214	-0.145
	M	*-0.0833*	1.442	*-0.392*	1.185	0.981	0.330	-0.114
Linguistic Capital	B	-0.250	1.775	-1.078	1.369	-2.218	0.0297	***-0.251***
	H	0.958	1.160	-0.373	1.356	-4.144	0.0001	***-0.436***
	N	*0.208*	1.414	*0.431*	1.269	-0.685	0.496	0.080
Familial Capital	C	-1.167	1.341	0.039	1.587	3.218	0.0019	***0.353***
	I	0.125	1.702	-0.333	1.275	-1.301	0.198	-0.150
	O	*0.208*	1.250	*-1.078*	1.055	4.639	0.0001	***-0.477***
Social Capital	D	-1.000	1.319	-0.0196	1.435	2.830	0.006	***0.314***
	J	0.917	1.501	0.961	1.113	0.143	0.887	0.0167
	P	*0.792*	1.474	*-0.196*	1.357	2.861	0.006	***-0.318***
Navigational Capital	E	0.667	1.494	1.078	1.23	1.261	0.211	0.146
	K	1.083	0.974	1.039	1.058	-0.173	0.863	-0.020
	Q	*-1.208*	1.103	*-1.137*	1.077	-0.265	0.792	0.031
Resistant Capital	F	1.208	1.414	0.941	1.287	-0.813	0.419	-0.095
	L	-0.958	1.268	-1.000	1.166	-0.140	0.889	-0.016
	R	*-0.625*	1.209	*-0.588*	1.268	-0.119	0.906	0.014

Item C scored p = 0.0019, and the PBC value of 0.353 suggests that non-First-Generation students are more likely to have family members that can relate to them and share stories. Yet, Item O scored p = 0.0001, and the PBC value of -0.477 suggests that First-Generation students had family members who understand engineering and their desires to pursue engineering as a future career more so than non-First-Generation students.

Items D and P in Table 5 represent the "Positive" and "Negative" elements of the Social Capital dimension. Item D prompted respondents about their having a group of older working professional friends who offer them advice about challenges in engineering while Item P prompted respondents about their having a sense of being on their own when it comes to their engineering pursuits.

Table 6. Item analysis between White Students (n = 47) and Students of Color (n = 26). *Italicized* items and means have been negated; and ***italicized, bolded*** font indicates a result with statistical significance.

Dimension	Item	White Students		Students of Color		Statistical Test		
		Mean	Std. Deviation	Mean	Std. Deviation	t-value	p-value	PBC
Aspirational Capital	A	1.413	0.739	1.231	0.951	-0.760	0.450	-0.090
	G	1.000	1.161	1.692	0.549	2.862	0.006	***0.322***
	M	*-0.340*	1.356	*-0.192*	1.096	-0.477	0.635	0.057
Linguistic Capital	B	-1.522	0.997	0.500	1.556	6.012	0.0001	***0.628***
	H	-0.435	1.283	0.885	1.275	4.324	0.0001	***0.456***
	N	*0.723*	1.117	*-0.231*	1.451	3.136	0.003	***-0.349***
Familial Capital	C	-0.109	1.591	-0.808	1.524	-1.830	0.072	***-0.212***
	I	-0.478	1.371	0.308	1.594	2.317	0.023	***0.265***
	O	*-0.915*	1.176	*-0.231*	1.366	-2.246	0.028	***0.268***
Social Capital	D	-0.304	1.387	-0.385	1.799	-0.184	0.855	-0.022
	J	0.696	1.284	1.308	1.192	2.034	0.046	***0.235***
	P	*-0.128*	1.329	*0.577*	1.554	-2.041	0.045	***0.236***
Navigational Capital	E	1.000	1.409	0.846	1.515	-0.340	0.735	-0.040
	K	0.936	1.030	1.231	1.032	1.169	0.246	0.137
	Q	*-1.149*	0.999	*-1.192*	1.234	0.163	0.871	-0.019
Resistant Capital	F	0.935	1.184	1.231	1.210	0.465	0.390	0.102
	L	-0.936	1.187	-1.154	1.084	-0.773	0.442	-0.091
	R	*-0.638*	1.223	*-0.500*	1.304	-0.452	0.653	0.054

Item D scored p = 0.006 between the two groups, and the PBC value of 0.314 suggests a moderately strong result that non-First-Generation students are more likely to have a group of older working professional friends who offer them advice about challenges than First-Generation students. Yet, Item P scored p = 0.006, and the PBC value of -0.318 suggests that First-Generation students feel less on their own as it relates to their engineering pursuits than non-First-Generation students. We additionally categorized our respondents into a comparison between White Students and Students of Color (see Table 6), and observed statistical significance across nine items (B, C, G, H, I, J, N, O, and P) representing four unique CCW dimensions (Aspirational, Linguistic, Familial, and Social).

Item G in Table 6 represents a "Positive Developing" element of the Aspirational Capital dimension. Item G prompts respondents for the continued motivation to reach their goals to become an engineer someday despite presently struggling to earn the best grades in their engineering classes. Item G scored p = 0.006, and the PBC value of 0.322 suggests that Students of Color are more likely to agree with struggling in their coursework while maintaining aspirations to become an engineer someday in comparison to White Students.

Items B, H, and N in Table 6 represent "Positive," "Positive-Developing," and "Negative" elements of the Linguistic Capital dimension. Item B prompted respondents about their ability to speak or write about engineering in more than one language while Item H prompted respondents about the importance of learning to speak or write in more than one language in relation to their future as engineers. Item N prompted respondents about the necessity to speak and write in more than one language for them to become an engineer. Item B scored p = 0.0001 between the two groups, and the PBC value of 0.628 suggests a strong result that Students of Color are more likely to have the ability to speak or write about engineering in more than one language than White students. Similarly, Item H scored p = 0.0001, and the PBC value of 0.456 suggests that Students of Color desire the ability to speak or write in more than one language in their futures as engineers more importantly than White Students. Item N scored p = 0.0025 between the two groups, and the PBC value of -0.349 suggest a moderately strong result that White Students are more inclined to report that it is likely required to speak or write in more than one language to become engineers.

Items C, I, and O in Table 6 represent "Positive," "Positive-Developing," and "Negative" elements of the Familial Capital dimension. Item C prompted respondents about their family's ability to relate to them and tell them stories about other engineers or professionals in the family, while Item I prompted respondents about their elder family members not understanding engineering, but having younger family members that do. Item O prompted respondents that no one in their family could understand engineering or their goals to become engineers someday. Item C scored p = 0.072 value between the two groups, and the PBC value of -0.212 suggests a strong result that White Students are more likely to have family that can relate to them and share stories about engineering family members than Students of Color. The item I scored p = 0.023, and the PBC value of 0.265 suggests that Students of Color are moderately more likely than White Students to have younger family members that they can relate to about their engineering pursuits despite older family members not understanding engineering. Item O scored p = 0.028 value between the two groups, and the PBC value of 0.268 suggests a moderately strong result that Students of Color are more likely than White Students to have some family that can understand engineering or their goals for becoming an engineer someday.

Items J and P in Table 6 represent “Positive-Developing” and “Negative” elements of the Social Capital dimension. Item J prompted respondents about their having a group of friends who help them make sense of challenges in engineering coursework and opportunities in professional development while Item P prompted respondents about their sense of being on their own when it comes to understanding challenges in coursework and opportunities in professional development. Item J scored p = 0.046 between the two groups, and the PBC value of 0.235 suggests a moderately strong result that Students of Color are more likely to have a group of friends who offer them advice about challenges encountered in engineering than White Students. Similarly, Item P scored p = 0.045, and the PBC value of 0.236 suggests that Students of Color feel less alone than White students in their engineering pursuits.

Summarily, Table 7 shows a significant statistical result (p = 0.0002) that Students of Color generally scored higher than White Students on a combined index of the six forms of capital measured in the survey with a PBC value of 0.4298.

Table 7. Comparison of White Students (*n* = 47) and Students of Color (*n* = 26) across a combined index of the six forms of cultural assets.

White Students		**Students of Color**		**Statistical Test**		
Mean	Std. Deviation	Mean	Std. Deviation	t-value	p-value	PBC
-0.3404	5.8617	5.1154	4.9746	-4.0108	0.0002	0.4298

Discussion

In seeking to answer our research question: “What cultural assets do undergraduate engineering students use in their development as engineers?” we observe in Table 3 that engineering students readily draw upon Aspirational, Social, and Navigational cultural assets with calculated means of the Likert scale numerical conversion being 0.764, 0.244, and 0.280, respectively. These calculated means are positive, meaning that respondents more often Strongly Agreed or Agreed with “Positive” and “Positive Developing” items, and more often Strongly Disagreed and Disagreed with “Negative” items. Carbajol (2015) previously identified through interviews the explicit expression of Aspirational and Navigational capitals specifically as most commonly referred to by students. While these three capitals were most prevalent, all six cultural capitals were present in students through our survey, a finding that is similarly supported by other literature and methodologies [Chavez, 2018; Martin, 2016]. Assets such as these capitals allow students to persist through a major, like engineering, that historically has low retention rates and discriminatory practices [Marx and Meyer, 2015; French, 2005].

Specific to our own findings, the strongest cultural asset that our respondents appear to have is Aspirational Capital with a score of 0.764. Items A and G scored positively, suggesting that our students had high aspirations to develop as engineers in the future despite facing little to moderate challenges in their present, day-to-day lives. Yet, Item M suggests that our respondents are losing their motivation to persist in engineering, which is aligned with other studies that report a loss of engineering student motivation to persist in engineering majors due to the number of barriers they may be encountering [Suresh, 2006; French *et al*., 2005].

Our respondents also had Social Capital cultural assets with a score of 0.244, and they are seemingly investing in this cultural asset by creating networks of near-aged friends and peers who help them make sense of their engineering efforts in their present, day-to-day lives (Item J) without necessarily having a network of older friends who are already engineering professionals (Item D). Our respondents' investment in networks of support among peers contributes to their sense that they are not alone in their efforts to become engineers someday in the future (Item P). Other studies have found the important role that a network of supportive family and friends has in supporting persistence in engineering and STEM majors [Martin *et al*., 2020; Patrick & Prybutok, 2018; Martin *et al*., 2013]

Our respondents had a score of 0.280 for their Navigational Capital, where they generally agreed that they know who to reach out to when they had questions about engineering employment opportunities (Item E) and the importance of professional networking at Info-Sessions (Item K). Our respondents see high value in a resume that cannot be overlooked in addition to developing their professional networks (Item Q). Other studies confirm that engineering students see the value of the professional network as it relates to their future in engineering [Martin *et al.*, 2014] and the value of badging or micro-credentials as a means of showcasing achievements to prospective employers [Gregg *et al*., 2022; Ifanthaler *et al*. 2016]

Additionally, it appears that the respondents to our survey held very few or very weak cultural assets across the Linguistic, Familial, and Resistance dimensions of the instrument, scoring calculated means of the Likert scale numerical conversion to values of -0.133, -0.400, and -0.187, respectively (at least in the manner by which the items sought to measure those four dimensions). These findings suggest that our respondents either do not use those assets or those cultural assets are used by a different demographic of students in other ways. To explore the nuances of how different demographics of students may have used those cultural assets in other ways, we now discuss how First-Generation students and Students of Color seemingly used their cultural assets.

First-Generation engineering students uniquely use Linguistic and Familial cultural assets. We found that First-Generation students who participated in our survey draw upon their Linguistic, Familial, and Social Capitals more readily when compared to non-First-Generation students (see Table 5). The understanding and belief that First-Generation students possess unique cultural resources to their peers are evident in many other additional studies [Verdin & Godwin, 2015] and our survey results suggest these differences are emergent in the Linguistic and Familial capitals they possess and leverage.

First-Generation students readily draw upon their Linguistic Capital assets as it relates to having (and sensing importance) to speak or write about engineering in more than one language (Items B and H). Moreover, First-Generation students tend to agree that it is necessary to speak or write about engineering in more than one language, particularly as it relates to their future (Item N). This observation is likely strongly correlated to our finding that Students of Color are more likely to be First-Generation students, and Students of Color may have a greater propensity to speak or write in more than one language [Mejia *et al*., 2020; Ong *et al*., 2020].

The second asset First-Generation students disproportionately draw upon is Familial Capital. Although they report a lack of access to existing family members who understand their day-to-day lives as engineering students and understand their long-term goals to become an engineer (Item C), First-Generation students report having more family members who understand their goals and aspirations to become an engineer someday. Non-First-Generation students report the opposite situation (Item O). This finding connects to other studies that note positive support that First-Generation students may have from their families without necessarily being able to draw upon any specific family expertise in meeting those goals [Covarrubias *et al.,* 2019; Gofen, 2009]. A takeaway from recognizing this phenomenon is the need to supplement First-Generation students' familial support with communities of professional support like professors and mentors who can help guide them along their collegiate journey [Torvi *et al*., 2022] as currently, First-Generation students find support through other means in their development as engineers. Mentors can be a tool to strengthen feelings of belongingness among First-Generation students and ease their struggles with professional connections [Boone & Kim, 2016]. Our survey results relate to these observations, where First-Generation students report a lack of access to older friends who may be professional engineers who can offer counsel (Item D), yet feel like they are not alone in their professional formation as engineers (Item P).

Engineering Students of Color use the most cultural assets. While not all First-Generation students who participated in this survey are Students of Color, we did find that Students of Color are more likely to be First-Generation students (see Table 7). When we inspected our demographic groupings between White Students and Students of Color, we found that engineering Students of Color readily drew upon their cultural assets across four dimensions: Aspirational, Linguistic, Familial, and Social Capitals - the most assets strongly drawn by any other demographic grouping.

First, Students of Color maintained higher hopes for their future despite facing challenges in the present when compared to White Students (Item G), reflecting their Aspirational assets. This finding mirrors other studies exploring populations of Students of Color, finding that of the six capitals, Aspirational Capital is one of the most identified capitals recognized [Samuelson & Litzler, 2016], despite encountering challenges and obstacles while persisting through STEM majors [Bonous-Hammarth, 2000]. This suggests that Students of Color's internal, aspirational mindset to persist in engineering and STEM majors are continually rebuffed by the lack of resources in attaining engineering and STEM degrees.

Second, Students of Color reported high abilities and motivations to speak or write about engineering in more than one language (Items B and H) yet reported not seeing value in leveraging these linguistic skills in their futures as engineers (Item N). White Students, on the other hand, reported a sense that speaking or writing about engineering in more than one language is important in their futures as engineers (Item N). This comparison interestingly points out how Students of Color undervalue their existing Linguistic and Cultural assets in their future lives as engineers. This disconnect presents an opportunity for engineering educators to emphasize the value of translanguaging [Wilson-Lopez & Acosta-Feliz, 2022; Budinoff & Subbian, 2021; Mejia *et al*., 2020] and multilingualism in the globalized engineering workplaces of the 21st Century.

Third, while Students of Color report not having family members understand their day-to-day pursuits in engineering (Item C), they do report having Familial assets in younger family members who are able to relate to their engineering goals (Item I) and having overall familial support. Students of Color's familial support for their efforts in engineering is stronger than White Students' sense of having overall familial support (Item O). Other research has found that minoritized students often find themselves without mentors and are the first in their families to navigate the bureaucracies of colleges and institutions of higher education [Cromley *et al*., 2016; Whitaker & Montgomery, 2012]. Yet, they also find themselves emerging as role models for others younger than themselves [Miller *et al*., 2023].

Lastly, Students of Color report social assets that help them not feel alone in their pursuit of engineering as a career (Item P), and they additionally report relying on a group of friends to navigate engineering in their present lives (Item J). Another study that explored ALANA students (African Americans, Latino/as, South East Asians, and Native Americans) similarly identified the presence of Social Capital within this population [Byars-Winston *et al.*, 2010]. In that study, the researchers found that the more students connected with people outside of their personal ethnic group, the more confident they felt in their academic and professional work [Byars-Winston *et al.*, 2010]. This implicitly suggests students feel more prepared and successful after talking to people because they have additional knowledge or resources to complete a task, showing an increased presence of social capital.

Implications of our findings. The totality of our findings reveals that engineering students do, in fact, use their cultural assets to meet the needs of their engineering coursework and foresee pathways to secure their future as engineers. Most students maintain some form of Aspirational, Social, and Navigational Capital while First-Generation students also draw heavily on Social Capital and uniquely leverage their Linguistic and Familial Capital. Students of Color drew upon the most cultural assets of all demographic groups explored - Aspirational, Linguistic, Familial, and Social. The presence of these cultural assets presents opportunities for engineering educators to leverage them in the engineering classroom and the engineering curriculum.

First, as it relates to engineering education instructional practices, educators would do well to adopt specific practices that reinforce student motivation to persist in the engineering major through affirming efforts that close the disconnect between student's aspiration to pursue engineering and the sense that they are losing motivation to persist in the major. Examples of affirming practices include meaning-making activities that connects students' present experiences or students' personal values to their future selves [Ling-Siegler *et al*., 2016] and develop their self-efficacy [Chyung *et al*., 2010; Colbeck *et al*., 2001; Ponton *et al*., 2001]. Moreover, educators can potentially leverage engineering students' social assets through team-based, project-based work that examines real-world contexts of engineering applications. When carefully designed, those experiences can foster students' sense of belonging [Taylor & Hernandez, 2022; Buckley *et al*., 2019]. Orientating such projects toward real-world scenarios - like sustainability performance, or environmental justice - can additionally awaken and foment Resistance Capital assets in engineering students. The exploration of real-world contexts that involve differing communities or regions in the country (or world) can promote the development of different modes of communication, which holds the potential to leverage and strengthen linguistic assets.

Second, as it relates to engineering curricula, we speculate on the ability to measure the cultural assets inherent to the student population in any particular engineering degree program. Measuring these assets can therefore be used as a tool to identify the extent to which that program's engineering students are socializing and networking within an engineering space and culture. Such an exploration can also illuminate insights into how these student interactions with others affect their confidence and self-efficacy in the major, particularly as program-level interventions are prototyped and deployed. Low self-efficacy has been linked to low retention rates in programs, particularly for Students of Color, so a measurement of Social Capital, as an example, is a way for a program to address issues in retention and align opportunities for Students of Color with goals of improving relations and confidence. Our findings also reinforce the need to challenge engineering students who report having very little or weak Resistance Capital. Other studies have found engineering students to shy away from notions of civic or social responsibility [Canney & Bielefeldt, 2015]; whereby students view engineering as a purely technical field of practice, devoid of any socio-technical implications [Castaneda *et al*., 2022]. This observation re-affirms engineering education leaders' call to adopt and employ ill-structured problems, wicked problems, and other ethically dubious, real-world engineering scenarios that promote engineering students' broader critical thinking skills.

Limitations of our study. As a newly developed instrument, it is important to take steps to ascertain the validity of the findings. One such technique is to explore the internal consistency of the respondents' entries. If a respondent indeed agrees with a "Positive" item in a specific dimension, then they are likely to disagree with a "Negative" item in that same dimension.

In Table 3, an agglomeration of all 75 respondents revealed internal consistency of the Familial dimension of the survey, whereby respondents who agreed with Items C and I disagreed with Item O. When segmented by demographic groupings (Tables 5 and 6), only the Familial dimension of the instrument in Table 6 remains internally consistent. As such, there are limited indicators that our findings across the Familial dimension of the survey are valid. Our discussion across the remaining dimensions of Aspirational, Linguistic, Social, and Navigational are, thusly, dependent on a more careful item-by-item analysis and merits a discussion on the shortcomings of those items within the overall instrument. Moreover, our measurement of Resistance Capital did not yield any statistical significance across any of our variance tests.

Our findings are likely limited by the response rate and sample size of our study. Our exploratory study recruited 75 survey respondents, which is a small sample size and presents a challenge for statistical treatments. Moreover, the small sample size makes it difficult to validate the instrument since it is a challenge to determine whether other survey dimensions (Navigational and Resistant) are cultural assets that can be detected in smaller demographic groupings. Our instrument conflated present-day activities (i.e., engineering coursework) with imagined future lives (i.e., as professional engineers), which may have led to internal inconsistencies within the six dimensions of our survey. Moreover, the cultural assets are acknowledged by Yosso (2005) to be dynamic and overlapping, which our survey design did not account for as we sought each item to measure only one specific CCW capital. Ongoing refinement of the instrument items is merited in order to enhance the internal consistency of our findings.

Conclusion

According to the National Science Foundation [NSF, 2023], the composition of learners has become increasingly diverse in engineering classrooms and engineering practice, meaning that engineering instructional practices must continue to evolve to leverage the existing skills and knowledge of the increasingly diverse population of students enrolled in the engineering classroom. Our exploratory study sought to measure those skills and knowledge in engineering students through the lens of Community Cultural Wealth (CCW). We designed an 18-item survey and distributed it to engineering students at three institutions of higher education in the United States (ASU, JMU and UCB). The survey sought to explore engineering students' use of their cultural assets to meet the needs of their engineering coursework and to foresee their future pathways in engineering. We found that engineering students do, in fact, use their cultural assets to meet the needs of their engineering coursework and foresee pathways to secure their future as engineers, particularly through some form of aspirational, social, and navigational capital. We found that First-Generation students also drew on social capital while also uniquely leveraging their linguistic and familial capitals. Students of Color drew upon the most cultural assets - aspirational, linguistic, familial, and social. These findings compare well to other studies and lend further credence that asset-based instructional approaches can be used to draw upon and strengthen engineering students' cultural assets as they develop into engineers.

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